Oracle Autonomous Database Technical Overview

Available in the Cloud or on-premises, Oracle Autonomous Database is self-driving, self-securing, and self-repairing.

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INTRODUCTION

Oracle Autonomous Database combines the flexibility of cloud with the power of machine learning to deliver data management as a service. It's built upon a foundation of technical innovations that have been developed by Oracle over the course of more than three decades, meeting the needs of thousands of enterprise customers worldwide. The foundation for Autonomous Database includes:

- Oracle Database Enterprise Edition
- Exadata Database Machine
- Oracle Cloud Infrastructure
- Oracle's Best Practices
- Oracle's Knowledge Base
- Machine Learning

Autonomous Database incorporates all of these technologies to deliver a database that is self-driving, self-securing, and self-repairing, allowing customers to focus energies on developing and delivering solutions that directly add value to their business. Each of these technologies provide powerful capabilities separately, but in combination these technologies deliver the revolutionary Oracle Autonomous Database.

Oracle Database Enterprise Edition

The foundation of Autonomous Database begins with Oracle Database Enterprise Edition, which is the same database that customers have used for years to run all manner of workloads including Data Warehouse, Analytics, and Transaction Processing. Autonomous Database uses automated configuration settings and eliminates management complexity as detailed later in this document.

Autonomous database is built on top of and automates many advanced database technologies that are unique to Oracle including:

- Real Application Clusters for scale-out, failover, and online patching
- Online operations for schema changes
- Active Data Guard for database aware Disaster Recovery
- Parallel SQL for high throughput
- Database Containers for agility
- Database In-Memory for high performance
- Transparent Database Encryption for data protection
- Database Vault for role separation

Exadata Database Machine

Beyond simply keeping pace with advances in computer hardware technology, Oracle became a driver in the hardware market when Exadata was introduced in 2008. Exadata is more than computer hardware with pre-installed Oracle database software. Exadata is the synthesis of software and hardware, where critical database functions are distributed across the hardware components. Other modern hardware platforms still follow a conventional compute + storage system architecture that does not operate in the same manner. Exadata storage does not simply store and retrieve blocks of data. The core database engine offloads critical functions to the Exadata storage to execute those functions with minimal movement of data. These offloaded functions include a wide range of critical operations, from filtering for changed blocks during incremental backup, to execution of SQL fragments during parallel analytic operations. Exadata also provides Remote Direct Memory Access to greatly accelerate SQL on scale-out clusters.

Oracle Cloud Infrastructure

Oracle Autonomous Database simply would not have been possible without the Oracle Cloud and a new generation of software-defined Infrastructure as a Service. The Oracle Cloud is architected for the full range of applications and databases, from small scale to enterprise-class applications requiring high performance and scalability. Oracle has thousands of customers running mission-critical systems that continue to push the bounds of computing technology. Oracle customers have workloads that exceed the capabilities of the largest computers available on the market, and only the Oracle database is able to address those needs through its clustering technology, Real Application Clusters. Oracle's Cloud infrastructure is designed with these needs in mind to deliver unmatched performance, security, and availability in the Cloud.

Oracle Best Practices

Oracle publishes "best practice" recommendations for deployment, configuration, and operations of products such as the Oracle Database and Exadata. These "best practice" recommendations evolve along with the evolution of underlying infrastructure components and the Oracle Database. Oracle's Database development team are the leading experts in Oracle technology and are the same team who have developed the Autonomous Database. Oracle works with customers worldwide to define best practices for using Oracle technology to achieve the highest availability, security, and performance and have implemented those same best practices in the Autonomous Database.

Oracle Knowledge Base

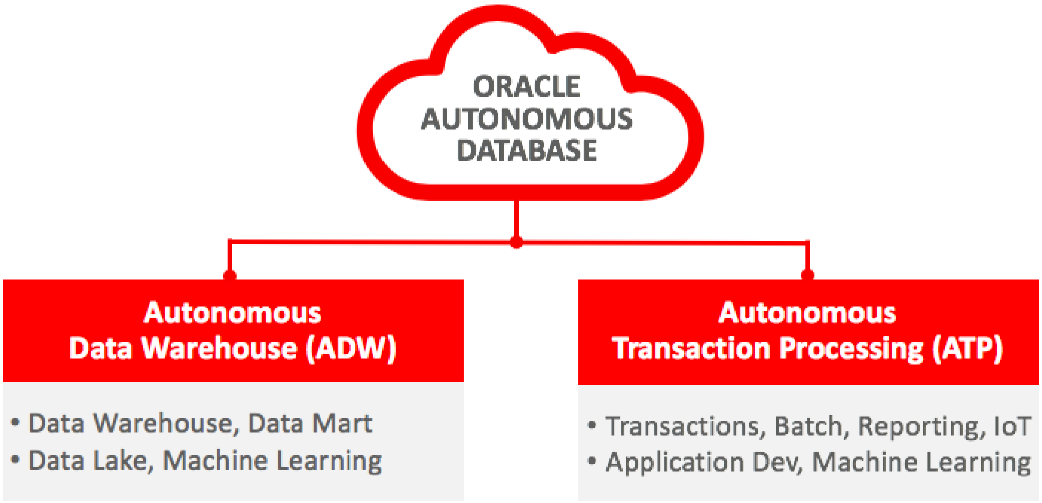
Oracle's base of knowledge extends beyond Oracle's Development team and includes Oracle's internal database of Service Requests, Enhancement Requests, and Bug Database. These databases include associated trace files, log files, and other supporting information used to diagnose and resolve issues. This knowledge base forms the data inputs required to build, and then train Machine Learning models needed to automate issue resolution in the Autonomous Database.

Machine Learning

Oracle databases can range in size from a few megabytes to hundreds of terabytes and beyond. Oracle databases can consist of just a few objects, or billions of objects. Workloads can include servicing web sites, financial systems, healthcare records, manufacturing, ERP, or virtually any business conceivable. Machine Learning plays a key role in the automation that defines the Autonomous Database. Machine Learning is also a set of tools available in the Oracle Cloud that customers can use to implement their own solutions.

AUTONOMOUS DATABASE SERVICES

The underlying converged database capabilities of the Oracle Database enable the Autonomous Database to be offered in two editions that are specifically tailored to a workload following Oracle's Best Practice recommendations. Oracle Autonomous Data Warehouse (ADW) is tailored to Data Warehousing, Data Marts, Data Lakes, and Machine Learning workloads. Oracle Autonomous Transaction Processing (ATP) is tailored to On-Line Transaction Processing, Batch, reporting, IoT, application development, machine learning, and mixed workload environments.


ORACLE AUTONOMOUS DATABASE
Autonomous Data Warehouse (ADW)
• Data Warehouse, Data Mart
• Data Lake, Machine Learning
Autonomous Transaction Processing (ATP)
• Transactions, Batch, Reporting, IoT
• Application Dev, Machine Learning

Autonomous Data Warehouse

As the name implies, Oracle Autonomous Data Warehouse (ADW) is tailored for Data Warehouse and related workloads including Data Marts, Machine Learning or as part of a Data Lake deployment. These systems and databases are generally separated from Transaction Processing applications and are constructed to meet specific business needs. Data Warehouses often use data modeling approaches such as Star Schema and other techniques to ensure data structures meet the needs of business users conducting data analysis, and Data Scientists performing trend-analysis. Data Warehouses typically house large volumes of data that is processed in bulk or streamed into the database. Data Warehouses often rely on summary data representation and highly parallel SQL to provide fast response times. Oracle Autonomous Data Warehouse is tailored specifically to these use-cases.

Autonomous Transaction Processing

Oracle Autonomous Transaction Processing (ATP) brings the same autonomous capabilities found in ADW into the Transaction Processing and mixed-workload arena. ATP is tailored primarily for complex Transaction Processing workloads that include operational reporting and/or batch data processing. The ability to run mixed workloads in a single database eliminates the need to move data from a Transaction Processing database into a separate reporting or analytics system. This capability reduces application complexity and eliminates the wait-time associated with movement of data between Transaction Processing and Analytic database services. ATP supports IoT and machine learning in addition to OLTP. By automating the creation and management of databases, ATP also makes application development much simpler.

Shared and Dedicated Exadata Infrastructure

Autonomous Database can be deployed on either Shared or Dedicated Exadata Infrastructure, and Oracle takes full responsibility for all aspects of service operation in either case. Shared Exadata Infrastructure provides the smallest minimum commitment, while Dedicated Exadata Infrastructure provides customers greater control over infrastructure operations. Each of these offerings provide important benefits as outlined below.

Shared

Oracle Autonomous Database on Shared Exadata Infrastructure gives customers the benefits of full isolation of data and system resources while also sharing infrastructure with other customers. The shared Infrastructure deployment option requires a minimum commitment of just one hour, one OCPU, and one Terabyte of database storage. It can be instantly scaled both in terms of CPU and/or storage fully online, enabling users to pay only for the resources used. It is an ideal choice for line of business, departmental applications or data marts as well as making an excellent sandbox for Data Scientist or developers.

In the Shared Infrastructure deployment, all customers and all of their databases are part of a unified and standardized set of operational processes, running the same software versions, update levels, and security patches, all scheduled and uniformly applied by Oracle autonomous service software. Shared Infrastructure is great for customers that want to be databases users without worrying about any database operations including software updates.

Dedicated

With Dedicated Infrastructure, customers have their own dedicated Exadata infrastructure in the Oracle Cloud, effectively giving them a Private Database Cloud within the Oracle Public Cloud. Oracle Autonomous Database on Dedicated Infrastructure runs inside a hardware enforced virtual cloud network, offering the highest level of isolation from other tenants. Users can easily configure one or more Container Databases on their dedicated Infrastructure, each of which can contain one or more Pluggable Databases.

Dedicated Infrastructure gives customer the opportunity to customize the Operational Policies used to control the provisioning of new database, the timing of updates, the availability, and the density of databases that they run on the infrastructure. Having control over database versions and the timing of upgrades is especially important for applications that are more sensitive to database version and release differences. Although customers can customize these Operational Policies, all operations are still fully automated by Oracle.

With Dedicated Infrastructure customers have the ability to define “fleet administrators” who manage the overall service, as well as individuals who can deploy and manage the databases themselves. It is an ideal platform for customers who are looking to rethink their IT strategy and move some or all of their database estate to a Cloud based solution.

Autonomous Database on Exadata Cloud@Customer

Some organizations are not able to deploy databases in the Public Cloud even when deployed on dedicated infrastructure in the Public Cloud. For this reason, Oracle Autonomous Database can also be deployed in a customer’s data center (or 3rd party outsourcing site) on dedicated infrastructure in the Cloud@Customer model. The most common reasons for using the Cloud@Customer model include:

- Regulations
- Latency
- Integration
- Risk

Many companies cannot easily move to public cloud due to challenges involving the regulatory nature of their data, data sovereignty laws requiring data to stay in country of origin, and the complexities of systems entanglement present in enterprise architectures. Systems entanglement happens because individual applications are coupled to others in such a way that changes to one impact the others, thereby complicating a move to public cloud. To mitigate these challenges while providing customers the benefits of cloud self-service and a pay-per-use financial model, Oracle introduced Exadata Cloud@Customer in 2017, bringing the cloud to customers who cannot simply transform to public cloud. Autonomous Database on Exadata Cloud@Customer (or on Dedicated Regions) delivers all the value of Autonomous Database to the customer's data center.

With Autonomous Database on Exadata Cloud@Customer, customers get the full advantage of Autonomous Database combined with the benefits of dedicated infrastructure in their own data center. More information on Oracle Autonomous Database and Exadata Cloud@Customer can be found at the following location: https://www.oracle.com/engineered-systems/exadata/cloud-at-customer.

PROVISIONING DATABASES

In a traditional data center environment, administrators perform a number of tasks to complete the database provisioning process. These tasks would typically take days or even weeks to complete.

- Identify and Allocate Compute & Storage Resources
- Install and Configure System Software
- Install and Configure Database Software
- Configure Oracle Grid Infrastructure
- Configure Oracle Real Application Clusters
- Install and Configure Monitoring Software

These tasks are all executed automatically with the Autonomous Database and any issues that might arise are either addressed automatically or by Oracle's Cloud Operations team.

Provisioning an Autonomous Databases is an extremely simple process where users provide a set of basic information to provision databases, as well as optional advanced settings as outlined in this section.

Basic Settings - User Selected Settings for Provisioning

Customers provision Autonomous Databases that are Highly Available (running RAC database on Exadata Infrastructure) in just a few minutes using either the service console or the REST API. Only a few simple pieces of information need to be supplied as follows:

Basic Provisioning Selections
Cloud Service Region
Workload Type (Data Warehouse vs. Mixed Workload)

Display Name
Database Name
CPU cores
Storage Space
Administrator Password
License Type (Database Software Included or Bring Your Own Licenses)

Databases are automatically provisioned within a few minutes to support the chosen type of workload. Oracle automatically takes a nightly backup of all Autonomous Databases, and backups are preserved for up to 60 days.

Optional Advanced Settings

Autonomous Database eliminates the need to set and manage complex configuration settings that control how Oracle databases operate. Those complex settings are managed automatically by Oracle, but a number of advanced settings are available to customers should they wish to adjust the localization (NLS) Settings, and or SQL Optimizer settings.

Localization Setting

Date, time, and currency display formats vary across the globe and may need to be set by customers according to the needs of their users and applications.

Localizations
DATE, TIME, TIMESTAMP, TIME ZONE, CALENDAR formats, etc.
Currency Display formats
Linguistic vs. Binary Sort Order

Of course, date, time, and currency display formats vary across the globe and need to be set by customers according to the needs of their users and applications.

Advanced Settings – SQL Controls

While the SQL Optimizer is managed automatically by the Autonomous Database, there are a number of controls that customers can use to influence how the optimizer operates if necessary, for their application or workload, as shown in the table below.

The Oracle Database includes a number of approximate functions that can be used rather than the corresponding exact calculations in order to improve performance. However, the results are not exact (not as accurate as the corresponding exact function). Not all applications can take advantage of approximate functions in the same manner but those that can should see a performance improvement. Customers can have Oracle automatically replace the corresponding exact calculations or function in their code with the approximate one by setting one or more of the approx. parameters in the table below. Note it's best to set these parameters only at the session level.

SQL Controls
APPROX_FOR_AGGREGATION
APPROX_FOR_COUNT_DISTINCT
APPROX_FOR_PERCENTILE

Optimizer Controls

Autonomous Database also gives customers control over 3 optimizer settings. SQL Plan Baselines are often used in transaction processing applications to prevent unexpected SQL execution plan changes. Setting the parameter OPTIMIZER_CAPTURE_SQL_PLAN_BASELINES to TRUE, gives the Autonomous Database permission to automatically generate SQL plan baselines for all repeatable SQL statements.

By default, ATP honors all optimizer hints, while ADW is configured to ignore optimizer hints. Customers can choose to change this behavior by modifying the parameters OPTIMIZER_IGNORE_HINTS and / or OPTIMIZER_IGNORE_PARALLEL_HINTS.

Optimizer Controls

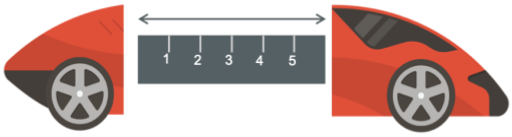
OPTIMIZER_CAPTURE_SQL_PLAN_BASELINES (ALTER SESSION ONLY)
OPTIMIZER_IGNORE_HINTS
OPTIMIZER_IGNORE_PARALLEL_HINTS

Decommissioning Autonomous Databases

The process of decommissioning an Autonomous Database is extremely simple. An administrator (with the proper privileges) uses the Oracle Cloud User Interface (or REST API) to select a database to be deleted and confirms the action. Behind the scenes, the Oracle Cloud automation removes all traces of the database in a secure manner to ready the system for another database to be created. An Autonomous Database is not simply removed from the Cloud Infrastructure, but it is erased using secure erasure methods to prevent access to data regardless of sensitivity.

SCALING

Autonomous Database services are billed based on the amount of compute and storage resources used each hour. In order to ensure customers only pay for the resources they need, when they need them, Autonomous Database includes the ability to instantly scale system resources online in order to meet the needs of the application and business. Scaling can be done manually via the Cloud User Interface or via the REST APIs (scripting) or automated via the built-in Auto-Scale feature.



Service Scale Settings

Unlike other cloud services, Autonomous Database does not require users to scale using predefined hardware shapes or configurations. Users have the ability to scale up or down either the number of CPU cores and or the storage space allocated to their configuration when needed.

The number of CPU cores and storage space is set during initial creation of the database and can be changed at any time as desired. For example, Autonomous Database can be easily scaled up and down by time of day, or day of week, or using other logic as desired.

Automatically Derived Settings

When Autonomous Database is manually scaled (via UI or APIs) a number of other key setting are also automatically scaled including:

Automatically Derrived Scale Settings
SGA Memory Allocation
PGA Memory Allocation
Database Session Limits
Parallel Query Process Limits
I/O Operations Per Second
I/O Bandwidth
Flash Cache Space

These settings are effectively derived from the basic settings (CPU and storage) as an equivalent percentage of physical resources available. Adding CPU gives more memory in the form of SGA and PGA, as well as additional processes and sessions. For Autonomous Databases on Shared Infrastructure, space in the Exadata Smart FlashCache is allocated as a percentage of the storage space allocated to the database, and I/O Operations Per Second (IOPS) and I/O Bandwidth are effectively a function of both CPU and Storage.

Controlling the number of configured OCPUs is the primary way users control overall performance of an autonomous database. Other performance settings are automatically scaled up and down as the number of CPUs are scaled keeping the system's CPU, I/O, and Memory balanced as performance needs vary.

Monitoring Utilization of Resources

Autonomous Database includes the tools necessary to easily assess resource usage and address issues that arise such as applications or SQL statements with very high resource usage. Performance Hub (PerfHub) provides a comprehensive view of how resources are used, which sessions are using them, and which SQL statement are using them and also provides usage history to enable problems that happened in the past to be diagnosed. Automatic Workload Repository Reports (AWR) and SQL Monitor can be used to perform even deeper inspection.

Automatic Scripted Scaling

Advanced users might consider using the REST API to scale Autonomous Database services through automated scripts to eliminate the need for manual intervention. For example, the cpuCoreCount attributes can be set via the REST API to increase or decrease the CPU cores assigned to the database based on time of day, day of week, etc. Automatic scripted scaling can also be used in combination with the auto-scale feature to provide dynamic scaling to better meet business needs regarding performance, capacity, and cost.

Auto-Scale Feature

Although scripted scaling offers flexibility and control over service scaling, the Auto-Scale Feature provides the ability to automatically scale within pre-defined boundaries in response to workload demands in real-time. The auto-scale feature begins with a baseline OCPU configuration and will automatically scale CPUs up to 3 times the baseline when workload increases. The baseline can be modified either manually or via REST API, and auto-scale will operate from the established baseline. The additional CPUs are only used when necessary and the Autonomous Database instantly returns to the baseline CPU when the workload no longer requires the additional resources.

Stopping and Starting Autonomous Service

Autonomous Database services can be completely stopped and billing for compute resources ceases while the service is stopped. Stopping production Autonomous Databases is not very common, but this capability is certainly useful for development, test and other non-production databases. QA (Quality Assurance) and training databases are also cases where Autonomous Database can often be shut down when the service is not in-use.

MANAGEMENT

Ongoing day-to-day management of an Autonomous Database is entirely automated. Space management, patching and upgrades, tuning, diagnosing errors and performing regular health checks is done automatically without requiring user intervention.

Automated Management

Oracle Autonomous Database includes the full set of products found in Oracle Exadata, and the Exadata Cloud Service, but all components are operated autonomously. To put this into perspective, Oracle Autonomous Database is built on the following components:

- Oracle Cloud Infrastructure
- Exadata Servers & Storage
- Internal Network Fabric
- Exadata Storage Server Software
- Oracle Virtual Machine
- Oracle Grid Infrastructure
- Oracle Real Application Clusters
- Oracle Database Enterprise Edition

All of these components are managed automatically in the Autonomous Database, including initial configuration, changes in response to scale up/down demands, and during service deletion. This section outlines how customers can view management actions that have been taken by Oracle or are scheduled to be executed. This section also outlines the management control that customers have over the service.

Automatic Updates

Autonomous Database with shared infrastructure is automatically upgraded to the latest versions of all software and underlying components. All updates are automatically executed by Oracle without disruption during periods of low service usage, and individual customers do not need to be concerned with timing of when updates are applied.

Rolling Upgrades & Application Continuity

Oracle Autonomous Database is built on a clustered systems foundation using Exadata, which provides for rolling upgrades. Workloads that follow Oracle Application Continuity requirements and best practices are moved one node of the cluster to another without impacting applications or users. Application Continuity includes moving sessions across cluster nodes even while transactions are in-flight. Transactions can often continue processing after moving to a different node without loss of session state. For more information on use of Application Continuity, please refer to the MAA paper on this topic here: https://www.oracle.com/technetwork/database/options/clustering/applicationcontinuity/adb-continuousavailability-5169724.pdf

Greater Control with Dedicated Infrastructure

For complex and mission-critical database applications, Dedicated Infrastructure allows customers to control software versions, patching schedules, database density, and finer control over the staging of Oracle software versions and patch levels from pre-production through production deployment. The additional level of control with Oracle Autonomous on Dedicated Infrastructure allows customers to separate development, test, and production environments so each is updated independently with a trust & verify model that allows validation of updates in pre-production environments before autonomous operations apply those updates to mission-critical production environments.

Service Health Dashboard

Customers can view system health, availability, and maintenance performed via the Service Health Dashboard, which shows the status of all OCI services including Oracle Autonomous Database Services. Customers can subscribe to updates from the Service Health Dashboard and view the record of past incidents at https://ocistatus.oraclecloud.com.

Fault Detection & Resolution

Faults can and do occur in any computer system, including hardware failures and software errors as well. Autonomous Databases are continually monitored for the full range of faults that might occur, and resolution is automatically launched in response. Examples of hardware faults include server failure, failure of disk drives, and NVMe Flash. Autonomous Database runs on fully redundant Exadata hardware that can experience and survive hardware failures without service interruption. Oracle's Cloud Operations team automatically dispatches a hardware technician to address any hardware failures.

Software faults are often avoided through proactive health monitoring and resolution to address issues before a system is impacted. Some software faults are addressed without service disruption, while other faults may result in some level of disruption such as terminated sessions. Regardless of the cause or impact of these faults, the majority of faults are monitored and resolved automatically in Autonomous Database without requiring customers to file Service Requests. Machine Learning built into Autonomous Database will resolve some faults automatically, while others may automatically engage an engineer from Oracle's Cloud Operations team to resolve the issue.

SECURITY

Information Security has become an even more critical topic in recent years due to increases in cyber security threats and breaches. Autonomous Database is built upon the foundation of the Oracle Cloud Infrastructure, which is an enterprise-grade Cloud service, delivering the highest possible security standards in the industry.

All data stored in and network communication with Oracle Cloud are encrypted by default. Autonomous Database builds upon this secure foundation through the following:

- Best Practice Security Configuration
- Automatic Security Updates
- Database Encryption
- Network Security Monitoring
- Encryption Key Management
- Oracle Database User Security
- Database User Password Controls
- Auditing Database Access
- Administrator Data Access Control
- Database Vault

Best Practice Security Configuration

Systems running Autonomous Database are secured using best practices for security at each level, including Virtual Machines, O/S, drivers, Exadata storage, Oracle Clusterware, Real Application Clusters, and Oracle Database. Autonomous Databases are continually scanned to ensure compliance with current best practice security configuration. If anomalies are detected, changes are automatically implemented without customer intervention. Autonomous Database also includes Oracle Data Safe, which provides comprehensive tools to ensure data security,

Automatic Security Updates

Security fixes are automatically applied as soon as possible, normally on a quarterly basis. Autonomous Database uses the Exadata product stack, which includes security fixes at each level from Virtual Machine and device drivers through Oracle Database. The stack is scanned for security issues using industry leading security scanners, and fixes are integrated into the stack before being applied to the Autonomous Database. Any emergency security updates are also the responsibility of Oracle and are also applied automatically on Autonomous Database.

Automatic Database Encryption

Oracle Autonomous Database uses Oracle's Transparent Data Encryption (TDE) technology as a standard (non-optional) configuration. TDE provides data-at-rest encryption for the Oracle database. Database backups are encrypted as well.

Network Security Monitoring

Oracle Autonomous Database operates within the Oracle Cloud Infrastructure (OCI), which includes robust network traffic security monitoring as a standard part of the service. For more information on security provided as part of the OCI environment, please refer to the Oracle Cloud Infrastructure Security white paper at https://cloud.oracle.com/iaas/whitepapers/oci_security.pdf

Encryption Key Management

Encryption/decryption keys are managed automatically as part of Oracle Autonomous Database Service without requiring customer intervention. Encryption keys are used to control encryption of data within the database, as well as encryption of network communication.

Database User Security

Users of the Autonomous Database are responsible for creating database users and schema owners. Customers use the ADMIN user to create and manage schema owner accounts which, in turn, create and manage application objects such as tables and indexes. Some databases on the market support only a single collection of objects within each database (what Oracle calls a schema), whereas Oracle allows tens, hundreds, or even thousands of schemas in a single database. Multiple applications, application modules, or microservices can share a single database, but still achieve sufficient isolation. Of course, customers can also choose to deploy as many Autonomous Databases as needed to address the requirements of application development teams.

Application Developers or Development DBAs use schema owner accounts to create objects used by the application including tables, indexes, triggers, stored procedures, etc. We will explore the role of Development DBA in greater detail in the section that follows. Customers use the ADMIN user to reset passwords of any schema owner accounts when necessary.

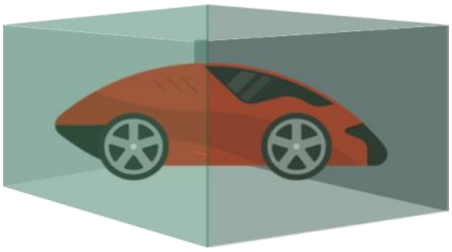
Oracle Data Safe also provides comprehensive tools for assessment of end security, monitor user actions and meet security compliance requirements.

Auditing Database Access

Customers can audit database access and other activities using Oracle Unified Auditing capabilities. Customers can view audit information using the OCI Service Console under GOVERNANCE (AUDIT).

DATA PROTECTION

Data protection is automatically configured once an Autonomous Database is created. Oracle Autonomous Database provides robust data protection due to the underlying architecture based on Exadata, as well as Oracle database backup/recovery capabilities.



Autonomous Database follows the principal of defense in depth, starting with the system configuration and following industry leading best practices for data protection, including Oracle Maximum Availability Architecture (MAA). The overall data protection scheme includes the following components:

- Redundancy & Resiliency
- Standard Database Backups
- Supplemental Database Backups
- Database Recovery
- High Availability
- Disaster Recovery

Redundancy & Resiliency – High Availability

Autonomous Database includes all of the built-in redundancy and resiliency features that are part of the underlying Exadata platform. Autonomous Database uses a high availability (HA) configuration as a non-optional, default configuration. Autonomous Database extends these HA capabilities to the application tier using Oracle Application Continuity. This high availability configuration of Autonomous Database allows application developers and users to focus on business requirements.

Standard Database Backups

The standard database backup uses a Weekly Full and Daily Differential Incremental (WFDDI) approach with a 60-day Recovery Window configured by default. This means that full backups are taken weekly, with incremental backups once per day. Backup of REDO logs are also included to give point-in-time recovery to any time or System Change Number (SCN) within the backup window.

Supplemental Database Backups

Database backups are automatically configured when an Autonomous Database is created, providing immediate data protection from the very inception of the service including recoverability up to a 60-day window. Customers can also supplement the standard backups as needed such as for compliance purposes. Additional backups can be taken either manually or via a Rest API and stored in Oracle's Object storage. Customers can retain those backups for as long as needed to meet regulatory compliance and business needs. Autonomous Database service does not automatically expire any supplemental (manual) backups, leaving customers the full control needed to meet business requirements. Commonly known as KEEP Backups, supplemental backups are retained until deleted by the customer.

Database Recovery

The Autonomous Database Console provides a simple interface to execute database recovery without specialized knowledge of tools such as Oracle's Recovery Manager (RMAN). The console lists the available backups within the defined Recovery Window, and the customer simply chooses the desired backup to restore or specifies the desired point-in-time for recovery. Oracle Autonomous Database automatically performs the database recovery using the appropriate level of resources allocated to the service such as CPU cores, storage, parallelism, etc.

Unlike traditional on-premise databases, customers only need to perform recovery in order to reset the database to an earlier point in time. Recovery is often used to repair databases due to issues such as physical corruption. In Autonomous Database, physical corruption will be normally be detected by the health framework and recovery initiated (if necessary) as part of the automated repair process. Customers should not normally need to intervene to execute recovery to repair databases corrupted by failure of infrastructure. The database recovery capabilities of Autonomous Database include the following:

- Database Repair
- Oracle Flashback
- Point-In-Time Recovery
- Recover to Copy

Database Repair

The most common form of database recovery is actually a repair operation that involves repairing physical corruptions by recovering a database to the last transaction executed. In the event of a physical corruption, the Oracle database generates error messages and trace files that will be captured by Oracle Autonomous Database operational monitoring tools. These types of failures will be addressed by Oracle Autonomous Database without user involvement aside from notification of such an event through the Cloud Service console. Autonomous Databases reside on Exadata, which is much less susceptible to physical corruptions, and therefore requires repair much less often than customers experience on other platforms or other Cloud services.

Oracle Flashback

Autonomous Database includes full support for Oracle's Flashback technologies, including Flashback Database, Flashback Table, and Flashback Query. Flashback is often used as an alternative to database recovery, especially for recovering individual tables, such as when a rogue user or transaction deletes or modifies data improperly. Flashback allows a Development DBA or other privileged user to view or make copies of data "as-of" a prior point in time, providing approximately 24 hours of recoverability. Beyond the 24-hour recovery window, customers should anticipate using database point-in-time recovery.

Point-in-Time Recovery

Point-in-Time Recovery refers to recovering a database to a specific point in time, which can be any point in time during the available Recovery Window. Autonomous Databases provide a Recovery Window of up to 60 days, meaning the entire database can be recovered or reset to any point in time (down to sub-second accuracy) within the past 60 days. This sub-second accuracy even goes down to the level of any System Change Number (SCN) within that 60-day window. Customers can configure supplemental backups to go beyond 60 days, including use of KEEP backups with indefinite retention such as for compliance reasons.

Recover-to-Copy

The Cloud Service Console provides a simple interface to restore an Autonomous Database to the point-in-time of a specific backup. The service console lists the available backups within the defined Recovery Window as well as any manual (supplemental) backups. The customer simply chooses the desired backup to restore and Oracle Autonomous Database automatically performs the database recovery. In other words, Recover-to-Copy is a specific case of point-in-time recovery, but simply references a specific backup rather than a designated point-in-time or System Change Number (SCN).

Data Protection on Cloud@Customer

Oracle Autonomous Database on Exadata Cloud@Customer is compatible with multiple data protection options including Oracle Zero Data Loss Recovery Appliance (ZDLRA), Network File System (NFS), Oracle Cloud Object Storage Service (OSS), or Fast Recovery Area (FRA) space configured on each machine.

Complex Recovery Scenarios

Oracle Autonomous Database services are designed to minimize operational complexity, which does include eliminating certain functionality. Autonomous Database does not currently directly support the following two complex recovery scenarios:

- Tablespace Point-In-Time Recovery
- Table Point-In-Time Recovery

Tablespace Point-In-Time Recovery (TSPITR) involves recovering a portion of a database (what's known as a tablespace) to a previous point in time. While table level point-in-time recovery is essentially supplanting TSPITR in the Oracle database in other environments, this capability is not currently available in Autonomous Database. Customers needing this functionality should use database cloning for point-in-time table recovery.

OPTIMIZATION

Optimization of a database refers to making optimal use of the resources assigned to that database. Administrators must determine the amount of resources assigned to a particular database and evaluate resource allocations on an ongoing basis. Please refer to the section of this document on scaling for more information on resource allocation. Database optimization in an Oracle database occurs at 3 levels, including service, system, and application schema level as outlined in this section.

Workload-Optimized Autonomous Database Services

Autonomous Database includes two services that are optimized for specific workloads:

- Autonomous Data Warehouse
- Autonomous Transaction Processing

Autonomous Data Warehouse (ADW) is optimized for Data Warehouse, Data Mart, and Analytic workloads. In ADW, data is automatically stored in Hybrid Columnar Compression (HCC) format. The Database In-Memory columnar format is automatically used in Exadata Flash Cache to accelerate analytic operations. In addition to being more space efficient, Hybrid Columnar Compression format provides more optimal data access for analytics.

Storage Indexes are automatically created both on disk and in Flash to help prune out any unnecessary data from data scans (see the section below for more information). Oracle Database Result Cache is also enabled by default for all SQL statements, so workloads with repetitive SQL (such as BI dashboards etc.) will benefit from accessing the results straight from memory rather than re-executing the same statement.

Given the volume of data typically stored in a data warehouse, it's impractical to think the typical working set could be cached in DRAM memory, which is why the majority of memory in ADW is allocated to improving the performance of parallel joins and aggregations.

Oracle Autonomous Transaction Processing (ATP) is optimized for Transaction Processing and "mixed-workloads" that include a mixture of Transaction Processing and operational reporting. In ATP, data is automatically stored in a row format to speed up transaction processing where each transaction is only interested in a small number of records (often one or two records/rows). The fastest way to find an individual record within a table is via in Index, which is why ATP not only supports manually created indexes but can also take advantage of Automatic Indexing (see the section below). Since transaction processing systems are so selective, it is very feasible and practical to cache the majority of the working set in memory, which is why the majority of memory in ATP is allocated to buffer cache.

Both ADW and ATP rely on Exadata and use the underlying features of Exadata such as SQL offloading and Exadata Smart FlashCache to meet the needs of the workload, and the automatic features differ depending on the intended workload type.

Automatic System & Storage Optimization

Optimization of the database at the system level is completely under the control of Oracle Autonomous Database and is done without requiring input from users of the database. System level optimization includes the following:

- System Global Area (SGA) Memory
- Process Global Area (PGA) Memory

- Database File Placement on Disk and/or Flash Storage
- Tuning of online redo logs and archival of redo logs
- Tuning of database backups

Automatic Schema Level Optimization

Automatic optimization of Autonomous Database at the application schema level is becoming increasingly more sophisticated. This capability currently addresses a number of the most common SQL optimization challenges as follows:

- Automatic Optimizer Statistics
- Indexing for Data Integrity Constraints
- Automatic Storage Indexes
- Automatic Secondary Indexing

Automatic Optimizer Statistics

Oracle Database uses a cost-based optimizer, which relies on statistics to determine the optimal SQL execution plan. Out of date (or "stale") optimizer statistics is a major source of SQL performance issues. Oracle Autonomous Database eliminates the need to manually gather optimizer statistics by automatically gather statistics in a number of ways. When data is bulk loaded into an Autonomous Database, statistics are automatically gathered as part of the load operation. During DML operations (insert, update or delete statements), critical statistics are automatically maintained. Autonomous Databases may also use high-frequency statistics gathering jobs to adjust any stale optimizer statistics.

Indexing for Data Integrity Constraints

Indexes are normally created on database objects such as relational tables to enforce data integrity. For example, a PRIMARY KEY or UNIQUE KEY constraint on a table uses an index to enforce that data integrity constraint. Simply defining those constraints results in indexes being created automatically. Constraints can be enabled and disabled as needed to facilitate data loading or other actions that temporarily violate constraint checks as needed by the application. While index creation for integrity constraints is not unique to Autonomous Database, this is an important component of the overall database optimization. Data access typically use these constraints and related indexes for SQL optimization.

Automatic Storage Indexes

Optimization in Autonomous Database takes into account the Storage Index feature of the underlying Exadata platform. Storage Indexes are automatically created by the Exadata software based on SQL filter predicates. The Exadata software examines offloaded SQL fragments to determine the relationship between those predicates and data values within blocks of data held by each Exadata storage cell. The Storage Index feature eliminates the need for secondary indexes in many cases, especially those indexes created for reporting workloads. This feature exists in the underlying Exadata platform and is a key component of optimization in Autonomous Database.

Automatic Secondary Indexing

Beyond use of indexes to ensure data integrity, additional indexing may be required for performance reasons. Primary Key/Foreign Key relationships and unique keys define some core data access patterns of any database schema, but secondary indexes are typically required as well.

Autonomous Database includes the automatic creation and management of secondary indexes. SQL statements are evaluated against existing indexes, and Autonomous Database determines whether additional indexes might be necessary for optimal performance. Autonomous Database automatically evaluates the benefits of new indexes and will test the change (automatically and independently) before implementing those indexes.

Automatic Indexing also monitors the usage of the indexes it implements. If an index is no longer useful it will be automatically removed. Removal happens after a specified amount of time to preserve indexes that are used infrequently.

Manual Schema Level Optimization

Autonomous Database allows manual optimization at the schema level that will not be altered by the system. Autonomous Database does not restructure the application schema, such as normalizing and de-normalizing the relational schema, and does not re-write SQL statements, PL/SQL code or any external code such as Java. Automatic optimization addresses optimization of the SQL and schema objects that have been defined by the application developers and data modelers. Manual schema-level optimization also includes the ability to implement even specialized indexing approaches such as Function-Based Indexes, Bitmap

Indexes, and Composite Indexes. This capability ensures customers have the widest possible range of capabilities to optimize business applications.

AUTONOMOUS DATABASE ADMINISTRATION

Autonomous Database brings an unprecedented level of automation to the operation of Oracle databases. Customers are able to exercise a degree of control over the service where required, with controls that are greatly simplified in comparison to legacy systems or other 3rd party Cloud services. In this and the following sections, we will explore what administrative functions are automated and what controls customers have over the service. Finally, we will also touch upon the tools available for monitoring and managing an Autonomous Database.

Automated Administrative Functions

Autonomous Database automates virtually all administrative functions for Oracle databases that normally consume a great deal of time and effort by Database Administrators, System Administrators, and other IT Professionals. Autonomous Database provides the following set of core automation capabilities that will be explored in greater detail in subsequent sections of this document:

- Provisioning
- Scaling
- Management
- Security
- Data Protection
- Optimization

Customers retain the degree of control necessary to deliver database services to meet business demands, while taking advantage of this unprecedented level of automation. Oracle provides a set of robust tools that allow customers control over Autonomous Database that integrates easily into the overall infrastructure of any enterprise, allowing customers to more easily adopt Autonomous Database without significant impact to Information Technology teams.

Cloud User Interface

The Oracle Cloud User Interface (UI) enables customers to control the lifecycle of Autonomous Databases. For example, provisioning, scaling, stopping, starting, upgrading, and recovering an Autonomous Database can be done through the Cloud UI. The Cloud UI also provides information intended to support those tasks, such as resource utilization and performance information needed for making scale up/down decisions.

Oracle SQL Developer

The Oracle SQL Developer tool is widely used by Oracle database administrators and application developers for working with Oracle databases and is fully compatible with Autonomous Database. SQL Developer includes the following User Interfaces:

- Graphical User Interface (Windows, Mac OS, Linux, etc.)
- Command Line Interface
- SQL Developer Web

The SQL Developer graphical user interface for Windows, Mac OS, Linux and other platforms is fully compatible with Autonomous Database. SQLCL (SQL Developer Command Line) is bundled with the full graphical version for each platform but is also available as a separate (smaller) download where only command line features are required. The SQL Developer Web interface is nearly identical to the Graphical Interface but runs in a web server and is accessible through a standard internet browser. As of this writing, SQL Developer Web is only available with Oracle's Database Cloud Services. SQL Developer provides the following tools:

- Object Browser
- SQL Worksheet (SQL editor)
- Data Grids (Spreadsheet style interface)
- PL/SQL Procedure Editor

- Reports
- DBA Console
- Data Modeler
- Database Migration Tool
- Performance Hub

Application Development SDKs

Although application development SDKs are not typically used for Database Administration, admins often use these tools for automating common tasks or application maintenance jobs. Autonomous Database supports the full range of application development SDKs and programmatic interfaces available with Oracle Database. Native support for Oracle Call Interface (OCI), ODBC, and JDBC OCI Connections enables Autonomous Database to support the majority of tools on the market including all popular development tools and frameworks.

Cloud Orchestration Tool Integration

Autonomous Database supports common Cloud Orchestration tools such as Terraform, which allows users to manage, version, and persist IT infrastructure programmatically using the “infrastructure as code” model. The Oracle Cloud Infrastructure Provider (a Terraform Provider) is offered under an open source license.

Performance Analysis Tools

Autonomous Database includes automatic (real-time) statistics, automatic indexing, and automatic SQL plan management, relieving developers and DBAs from common and tedious performance tuning. It also gives developers and DBAs access to the same in-depth performance analysis tools found in Oracle Database to provide insight into performance of SQL and applications using Autonomous Database. These tools can be used to evaluate the effectiveness of a give database schema and functional correctness of SQL. Autonomous Database performance analysis tools also include the following:

- Cloud User Interface
- Performance Hub
- Oracle Automatic Workload Repository (AWR)
- SQL Monitor

SQL Plus & SQLcl

Oracle SQL Plus is frequently used by Database Administrators and Developers to execute ad-hoc queries, administer the database, and even to build simple application components. SQL Plus is fully compatible with Autonomous Database, and can be run on Oracle Cloud Infrastructure systems, from desktops, or other computers that have network connectivity to Autonomous Database. Autonomous Database also includes support for SQLcl, which includes most of the capabilities of SQL PLUS as well as advanced capabilities beyond those found in SQL Plus.

MIGRATION CONSIDERATIONS

Oracle Autonomous Database is ideal for new application development approaches such as the microservices architecture. Oracle Autonomous Database is easy to deploy and requires virtually no administration aside from the necessary level of control outlined in this document. Oracle Autonomous Database is also an excellent platform for hosting existing applications and provides an opportunity to adopt best practice recommendations as part of the migration process.

Oracle customers, partners, and independent software vendors need to be aware of several considerations related to migration to Oracle Autonomous Database. These topics are covered in more detail in Oracle Autonomous Database documentation.

Restricted Features & Initialization Parameters

Autonomous Database currently restricts some features of the Oracle database. These features are either less prevalent among customers, or these capabilities are provided in a different manner with Autonomous Database. The set of restricted features are subject to change as features are added to Autonomous Database. Customers should consult Oracle Autonomous Database product documentation to determine the current status of restricted features. Please see the related documentation appendices for ATP and ADW Experienced Users for more information and to review the current state of restricted features.

Elimination of Tablespace Management

Oracle Autonomous Database on Shared Infrastructure eliminates the need to manage tablespaces but does not eliminate tablespaces entirely. Experienced administrators will see that tablespaces do exist in Autonomous Database (such as by querying data dictionary views), but customers simply do not need to manage them. The following commands are disabled in Autonomous Database on shared Infrastructure:

- CREATE TABLESPACE
- ALTER TABLESPACE
- DROP TABLESPACE

Autonomous Database on Dedicated Infrastructure does allow customers to control tablespaces.

In addition, Oracle Autonomous Database ignores most of the physical properties clause when creating tables, indexes, etc. Eliminating management of tablespaces and other physical properties greatly simplifies administration and operation of Autonomous Database and simplifies the DDL (Data Definition Language) used.

Elimination of No Logging Operations

Autonomous Database Logs all operations to ensure recoverability. The use of no logging operations complicates and limits database backup and recovery but has little benefit on Exadata systems. No logging operations were used on traditional non-Exadata systems due to performance concerns that Exadata alleviates. Even extremely large databases with hundreds of terabytes have been deployed on Exadata with full logging enabled, including the use of FORCE LOGGING.

Elimination of Index Organized Tables

Index Organized Tables (IOT) have been used in limited circumstances to improve performance of sequential data access. This was a critical capability years ago on systems that provided much lower performance capabilities than modern platforms. In addition, Index Organized Tables are not widely used on Exadata due to the high-performance capabilities and database function offload on Exadata storage. Index Organized Tables are also more complex to manage and more likely to require DBA expertise, so have been eliminated in Autonomous Database.

Eliminating Legacy Data Types

Autonomous Database Serverless does not support legacy data types such as LONG and LOG RAW. These data types were superseded by Large Objects (LOB) in Oracle8i, more than 20 years ago. Large Objects are much more flexible and feature rich than the older LONG data types. For customers who require these older datatypes, Autonomous Database Dedicated does include this support for backward compatibility.

ADB Schema Advisor

The Autonomous Database (ADB) Schema Advisor is a lightweight PL/SQL package that generates a report highlighting the schema objects that can and cannot be migrated, as well as those that can be migrated with changes. The ADB schema advisor is available for download via My Oracle Support under Doc 2462677.1 and works on Oracle database 11.2 and above.

CONCLUSION

Oracle's Autonomous Database is available in the Oracle public Cloud as well as on-premises in customer data centers for customers who cannot move to the public Cloud. Oracle Autonomous Database automates virtually all Operations DBA functions, allowing customers to focus on building and deploying applications that more effectively meet business requirements. Automation layers in the Oracle Cloud automatically detect and correct issues much faster and more accurately than even the most seasoned professional can accomplish using traditional manual methods. Oracle Autonomous Database is built on the Oracle Cloud Infrastructure, which keeps systems constantly updated with the latest fixes and security patches, giving developers immediate access to the latest innovations in the Oracle database. Autonomous Database is built on Oracle's Exadata Database Machine which delivers the high performance and cost-effective operation customers require for their most demanding and mission-critical applications.

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