

# Oracle Database 19c

Introduction and Overview

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## PURPOSE STATEMENT

This document provides an overview of features and enhancements available with Oracle Database 19c. It is intended solely to help you assess the business benefits of upgrading to Oracle Database 19c and to plan your I.T. projects.

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Due to the nature of the product architecture, it may not be possible to safely include all features described in this document without risking significant destabilization of the code.

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## INTRODUCTION

Oracle Database 19c is the final, and therefore 'long term support' release of the Oracle Database 12c family of products (which includes Oracle Database 18c). 'Long term support' means that Oracle Database 19c comes with 4 years of premium support and a minimum of 3 years extended support.

Oracle Database 19c builds upon the innovations of previous releases such as Multitenant, In-Memory, JSON support, Sharding and many other features that enable Oracle's Autonomous Database Cloud Services. This latest release of the world's most popular database also introduces new functionality, providing customers with a multi-model enterprise-class database for all their typical use cases, including:

- **Operational** database use cases such as; traditional transactions, real-time analytics, JSON document stores and Internet of Things (IoT) applications
- **Analytical** database use cases such as; traditional and real-time data warehouses and data marts, big data lakes and graph analytics

This white paper discusses some of the critical capabilities of Oracle Database 19c that can help customers deliver the best performance, scalability, reliability and security for all their operational and analytical workloads, whether for deployment on-premises, in-cloud or in hybrid configurations.

## JOURNEY TO AUTONOMOUS DATABASE CLOUD

Over successive database releases, Oracle has introduced innovative automated features that have helped administrators deliver a superior level of service to their end users. These innovations include:

- **Cost-based Optimization** Automatic SQL query optimization, automatic statistics gathering, automatic query rewrite automatic SQL Plan management and automatic SQL tuning.
- **Performance Tuning and Diagnostics** Automatic memory and resource management, automatic index and materialized view advisors, Automatic Database Diagnostic Monitor, Automatic Database Workload capture & replay and Automatic Workload Repository.
- **Data Optimization** Automatic undo management, automatic segment space management, Automatic Storage Management, Automatic Data Optimization and automatic columnar cache.
- **Cloud-Scale Operation.** Automatic standby management (broker), Diagnostic Framework, Multitenant Architecture, automatic database clone refresh and machine learning in Cluster Health Advisor.

In March 2018, Oracle introduced the Autonomous Data Warehouse (ADW) cloud service, and this was followed in August 2018 with the introduction of the Autonomous Transaction Processing (ATP) cloud service. By utilizing automated database functionality with machine-learning techniques, these Autonomous Database Cloud services can provide a level of performance and reliability that manually managed databases struggle to deliver. The Oracle Autonomous Database is specifically designed to provide customers with a higher level of service at lower cost by automating routine administrative tasks and eliminating human error through:

- **Self-Driving.** With easy to define workloads and policies, automation then makes them happen.
- **Self-Securing.** With automated protection from both external attacks and internal users.
- **Self-Repairing.** With automated protection from all downtime.

The Oracle Autonomous Database is built on top of the world's most widely proven enterprise-class database: Oracle Database, it runs on the world's best database platform: Oracle Exadata, and available as pay-as-you-go services on Oracle Cloud and Exadata Cloud at Customer (for public cloud and private cloud deployment respectively). In addition, machine learning for performance diagnostics and recovery optimizations are built into each layer of the deployment stack.



Figure 1. Oracle Autonomous Database Machine Learning

## MULTITENANT ARCHITECTURE

Designed for the cloud (public or private), Oracle's multitenant database offers a unique architecture that simplifies consolidation and delivers the high density of schema-based consolidation, but without requiring changes to existing applications. In this architecture, a single multitenant container database (CDB) can host many 'pluggable' databases (PDBs). Each database consolidated or 'plugged in' to a multitenant container looks and feels to applications the same as for pre-multitenant Oracle databases. By consolidating multiple databases into a multitenant container, many pluggable databases share the container memory and processor resources, thereby enabling a greater level of database consolidation density. In addition, all PDBs in a CDB are all effectively "managed as one" for database backup, patching, upgrading and standby operations. Oracle's multitenant database also enables greater administrative agility with rapid database provisioning and online operations such as:

- **PDB Hot Clone** enables fast instantiation of PDBs without having to take users offline.
- **PDB Refresh** enables cloned PDBs to be regularly updated with latest data.
- **PDB Relocate** enables PDBs to be relocated between CDBs with near zero downtime.

In addition, the Application Container capabilities of Oracle's multitenant database allow an application, formerly architected for standalone deployment on-premises, to be converted to an instant Software-as-a-Service (SaaS) architecture, with no code changes. The application is simply installed, unchanged, into an Application Root, and tenant PDBs (e.g. for separate customers) can share the application code while retaining secure isolation of tenant data. Application upgrades need only be applied to the single Application Root master and tenant PDBs simply synchronize with the upgraded master. Oracle's multitenant database has been widely adopted by ISVs and customers alike and deployed both on-premises and in the Cloud. Indeed, many Oracle Cloud Database Services including the Autonomous Database Cloud rely on multitenant for tenant isolation, agility and scalability. Oracle Database 18c added a number of enhancements to multitenant functionality including:

- **Faster Deployment of Upgrades, Updates and Revisions.** A new infrastructure further reduces the execution time of database upgrades, updates and revisions.
- **Transportable Backups** support the use of backups performed on a PDB prior to it being unplugged and plugged into a new container. This facilitates agile relocation of PDBs between CDBs, perhaps for load balancing or migration between on-premises and cloud, without requiring backups to be taken immediately before, and after, relocation of each PDB.
- **Snapshot Carousel** enables customers to define regular snapshots of PDBs that can then be used for a full point in time recovery or to a specific point in time clone. The Snapshot Carousel is ideally suited to development environments, that typically require multiple copies of databases at different points in time, or to augment a non mission critical back and recovery process.
- **Refreshable PDB Switchover** enables customers to create a PDB, which is an incrementally updated copy of a "master" PDB (e.g. from on-prem to Cloud) that may subsequently be switched over between each other. When this happens the "master" PDB becomes the clone and the old clone the master.

Oracle Database 19c further extends Multitenant's operational efficiency advantage with a number of enhancements, including a new CDB Fleet feature. In a CDB, we can manage many PDBs as one. Now, with CDB Fleet, we can manage many CDBs as one. The multitenant architecture of Oracle Database 19c cost-effectively enables tenant isolation, and agility with economies of scale, whether deployed in the Oracle Cloud, on-premises or hybrid cloud environments.

## PERFORMANCE

Oracle Database 19c inherits and enhances the raft of innovations in the areas of SQL query and data optimizations, and performance and tuning diagnostics that have helped customers deliver on database performance level expectations for operational, analytical and mixed workloads, on both single server and clustered server configurations. In addition, the unique performance features of Oracle Exadata, such as Smart Scans, Columnar Flash Cache and Storage Indexes, offer customers even greater levels of performance for all database workloads running on Exadata, either on-premises or in Cloud deployments.

### AUTOMATIC INDEXES

Without the relevant experience, optimizing database performance can be a challenge for many customers. Figuring out what columns in a table require an index to benefit not just a single query, but potentially thousands of variants requires a deep understanding of the data model, performance-related features of Oracle Databases and the underlying hardware. Oracle Database 19c alleviates this challenge with the introduction of Automatic Indexing which continually evaluates the executing SQL and the underlying tables to determine which indexes to create and which ones to potentially remove. It does this via an expert system that verifies the improvements an index might make, and after it's creation, validates the assumptions made. It then uses reinforcement learning to ensure it doesn't make the same mistake again. Most importantly, Oracle Database 19c is able to adapt over time as the data model and access paths change.

### DATABASE IN-MEMORY

Oracle Database 19c also offers customers an In-Memory column store accelerate analytic queries by orders of magnitude and improve the performance of transactional queries by eliminating analytic reporting indexes. Oracle Database In-Memory uses a unique dual-format architecture that simultaneously represents table data in its traditional row format, and in a pure in-memory columnar format. No changes to existing applications are required to take advantage of the IM column store, as the optimizer automatically routes analytic queries to the columnar format and transactional queries to the row format. Unlike other in-memory databases, Oracle Database In-Memory does not require the entire database to fit into main memory. It simply requires setting the size of the IM column store and identifying performance sensitive tables or partitions, and with Oracle Database 19c, the management of populating and removing objects from the IM column store can be automated. In addition, the IM column store is extended to flash on Exadata storage (both on-premises and Oracle Cloud), thereby dramatically enlarging the capacity of columnar formatted data. Oracle Database In-Memory's state-of-the-art algorithms for in-memory scans, joins and aggregations are widely proven to deliver orders-of-magnitude performance improvements for customers' analytical and mixed workloads. Typical use-cases for Oracle Database In-Memory include real-time analytics on operational workloads, where analytics are an integral component of business transactions, as well as data warehousing analytics and reporting systems. Oracle Database In-Memory's performance-enhancing features include; In-Memory Join Groups, In-Memory Expressions and in-memory processing of JSON queries. Customers can also maintain an IM column store on an Active Data Guard standby database running on Oracle Cloud and Oracle Exadata. This allows customers to make more productive use of their standby databases, isolating operational users from analytic users, and delivering high performance analytics against near-real-time data.

### MEMOPTIMIZED ROWSTORE

In addition to Oracle Database In-Memory column store, Oracle Database 18c introduced a Memoptimized Rowstore designed for fast query performance such as Internet of Things (IoT) workloads that require very fast and low latency lookups based on primary key values. The table level attribute, MEMOPTIMIZE FOR READ, is used to indicate which tables are to be pinned into the buffer



cache with this new hash index. Key-value lookups then bypass the SQL execution layer and execute directly in the data access layer via an in-memory hash index. This feature enables clients to perform very low-latency reads from the in-memory buffer, which can significantly increase the throughput of key-value lookups compared to conventional methods. The MemOptimized RowStore is further enhanced in Oracle Database 19c with MEMOPTIMIZE FOR WRITE that enables ingest of small, high volume transactions with a minimal amount of transactional overhead. The insert operations that use fast ingest functionality temporarily buffer the data in the large pool before writing it to disk in bulk in a deferred, asynchronous manner.

## REAL-TIME STATISTICS COLLECTIONS

Modern query optimizers require detailed statistics of the structure and make of data in tables to enable them to make the 'optimal' decision on how to execute complex queries. The problem with this is that statistics collection can be resource intensive and take some period of time. For most recent 'always on' applications, finding a window to run a batch process to collect this data is difficult. In Oracle Database 19c, statistics can now be collected as operations insert, update or delete data in real time. Now, there is no need for customers to compromise between the quality of the statistics that the optimizer depends upon, and finding the right time for statistics maintenance.

## QUARANTINE SQL STATEMENTS

Runaway SQL statements terminated by Resource Manager due to their excessive consumption of processor and I/O resources can now be automatically quarantined. This prevents these runaway SQL statements from executing again, and thereby protects Oracle Database 19c from a common source of performance degradation.

## HIGH AVAILABILITY

Oracle Database offers customers the highest levels of availability with Oracle's Maximum Availability Architecture; an integrated set of database availability feature and best practice blueprints that address the common causes on unplanned and planned downtime for both on-premises and in-Cloud deployments.

## UNPLANNED DOWNTIME

IT infrastructures are prone to failures such as server faults, disk crashes or storage corruption, site outages and human error that can incur costly unplanned downtime. In order to prevent and mitigate unplanned downtime Oracle Database 19c offers a number of key features to protect enterprise data from unplanned downtime, including:

- **Real Application Clusters (RAC)** enables multiple database instances to run on multiple servers in a cluster against a shared database. Since the servers run independently, the failure of one or more does not affect the others; RAC effectively removes the database server as a single point of failure.
- **Automatic Storage Management (ASM)** is the underlying (clustered) volume manager technology recommended for used with Oracle Database 19c. ASM stripes and mirrors everything for faster performance and offers a choice 2-or 3-way mirroring to protect data from disk failures.
- **Recovery Manager (RMAN)** manages Oracle database backup, restore, and recovery processes. It maintains configurable backup and recovery policies, and keeps historical records of all database backup and recovery activities, thereby ensuring that all files required to successfully restore and recover a database are included in database backups.
- **Oracle Secure Backup (OSB)** delivers scalable, centralized tape backup management for both database and file system data in distributed, heterogeneous IT environments. This includes RMAN



*backups to Oracle object store and Amazon S3 object storage.*

- **Flashback** enables reversing of human errors by efficiently undoing the effects of a mistake (e.g. an accidental table drop).
- **Active Data Guard (ADG)** enables protection from site failures by maintaining replica standby databases (synchronously or asynchronously) in alternative location. ADG also enable customers and offload read-mostly processing (e.g. backups, reports, analytics, etc.) to standby databases.

Oracle Exadata and many of Oracle Cloud's database services (e.g. Exadata Service and Autonomous Services) are built using these critical high availability capabilities using Oracle's Maximum Availability Architecture to offer customers the highest levels of database availability, both on-premises and on Oracle Cloud.

## PLANNED DOWNTIME

Planned downtime for essential maintenance such as hardware upgrades, software upgrades and patching are part and parcel of every IT operation. Nonetheless, downtime (planned or otherwise) can be costly and Oracle Database 19c offers a number of capabilities to help customers reduce the amount of planned downtime required for maintenance activities, including:

- **Hardware Maintenance and Migration Operations** Using Automatic Storage Management, disks can be added or removed online and the data is automatically rebalanced. Database servers can also be easily added or removed to a clustered database infrastructure while users remain connected. Cross platform incremental backup and recovery minimizes downtime for cross-platform hardware migrations, as does fast unplug and plug of PDBs between multitenant containers on different servers.
- **Online Patching** of database software can be applied to server nodes in a 'rolling' manner using Oracle Real Application Clusters. Users are simply migrated from one server to another; the server is quiesced from the cluster, patched, and then put back online. The same operation is then repeated for every server in the cluster.
- **Rolling Database Upgrades** Oracle Data Guard or Oracle Active Data Guard enables upgrading of a standby database, testing of the new (upgraded) environment and then switching users to the new environment, without any downtime.
- **Online Redefinition** Oracle Database allows changes to a table structure while continuing to support an online production system, and data files and partitions may be moved around storage devices while users continue to access underlying data.
- **Edition Based Redefinition** enables online application upgrades. Using edition-based redefinition, changes to program code can be made in the privacy of a new edition within the database, separated from the current production edition. An edition-based view exposes different projections of the same table into each edition, ensuring that the code in each edition only sees its own specific view of the table. Cross edition triggers propagate the data changes made by the old production edition into the new edition's columns, and vice-versa. This then allows both the old production environment and the new production environment to be used at the same time, for testing, and allows users to be moved online from one edition to the other.

## ENHANCING DATABASE AVAILABILITY

Oracle Database 19c continues to evolve the Maximum Availability Architectures with new and enhanced capabilities that help customers maximize their database availability, these include:

- **Data Guard Far Sync** provides zero data loss protection for a production database by maintaining a

synchronized standby database located at any distance from the primary location, without impacting database performance and with minimal cost or complexity. A far sync instance receives changes synchronously from a primary database and forwards them asynchronously to a remote standby. It's a lightweight entity that manages only a control file and log files, and only requires a fraction of the CPU, memory, and I/O resources of a standby database to relieve a primary database from serving remote destinations. Production can be quickly failed over, manually or automatically, to the remote standby database with zero data loss.

- **Global Data Services** provides inter-region and intra-region load balancing across Active Data Guard and Golden Gate replicated databases. It effectively provides Real Application Cluster failover and load balancing capabilities to Active Data Guard and Golden Gate distributed databases. Global Data Services extends the familiar notion of Database Services to span multiple database instances in near and far locations and can be used to distribute workloads across a reader farm composed of standby databases.
- **Auto Propagation of Nologged Data** is enabled in Oracle Database 19c, which means that customers no longer have to make compromises between no-logging to rapidly load data into their data warehouses and maintaining a replica standby database. Customers can now ensure that standby databases receive non-logged data changes with minimal impact on the speed of loading data into the primary data warehouse.
- **Application Continuity** effectively manages database failures from user-facing applications. For example, when a web application encounters any database outage it can result in transactions not completing properly or transactions being re-entered by the user. While the database outage can be easily recovered, the same may not be true for the application itself. Application Continuity enables failed transaction replay, effectively masking database outages from the end user.
- **Zero-Downtime Oracle Grid Infrastructure Patching** enables patching of Oracle Grid Infrastructure on clustered architectures without interrupting database operations. This is achieved in a similar manner to rolling database patching, by applying patches out-of-place in a rolling fashion, with one node being patched at a time.

## ACTIVE STANDBY DML REDIRECT

A popular feature of Active Dataguard is its ability to make use of standby databases for reporting and backups. In most disaster recovery solutions the standby does nothing other than continually recover logging information shipped from a primary database. While the ability to 'sweat' the standby is a big improvement in fully utilizing an enterprises resource, many reporting applications require the ability to persist some data even if it is simply a users preference. In Oracle Database 19c customers can now write to a standby database. These writes are transparently redirected to the primary database and written there first (to ensure consistency) and then the changes shipped back to the standby. This approach allows applications to use the standby for moderate write workloads without requiring any application changes.

## NATIVE DATABASE SHARDING

Oracle Database offers customers native database sharding for massive scalability and reliability for transactional applications. Critical high availability capabilities such as Real Application Clusters and Active Data Guard are widely proven to meet the needs of over 99% of transactional applications, while preserving application transparency. However, some global-scale transactional applications prefer to shard massive databases into a farm of smaller databases for scalability and reliability purposes. This requires designing applications around a sharding key, so that workloads are automatically routed to specific shards in a database farm. Oracle Database 19c provides the ability to ensure that data is placed in a location appropriate for its access with user defined "Range" and "List" sharding models. Oracle Database 19c also introduces full support for multiple pluggable database

shards within and across container databases.

#### ZERO DATA LOSS RECOVERY APPLIANCE (RECOVERY APPLIANCE)

The Oracle Recovery Appliance is an engineered system for standardizing backup and recovery process of Oracle Databases throughout the enterprise. It's an innovative data protection solution that is completely integrated with RMAN and designed to eliminate data loss exposure and dramatically reduces data protection overhead on database servers. The Recovery Appliance can easily standardize the protection of all Oracle databases in the data center with its massive cloud-scale architecture, end-to-end data validation, and fully automated management of the entire data protection lifecycle through Enterprise Manager Cloud Control.

## SECURITY

Enterprise data is increasingly under threat from malicious attacks, and regulations such as EU GDPR require organizations demonstrate stronger controls to protect sensitive data. From the outset, Oracle offers a multi-layered, defense-in-depth approach providing customers with evaluative controls for assessing the security posture of their databases and sensitivity of their data, preventive controls to block unauthorized access to data, detective controls to monitor user and application data access behavior, and data driven security to enforce user-and application-level data access controls at the source, within the database. These controls protect enterprise data stored in Oracle Database both on-premises and in the Oracle Cloud, include:

- **Transparent Data Encryption** helps protect against threats that target database storage and backup media devices. Encryption can be easily applied to entire tablespaces or to individual sensitive columns. Database encryption prevents access to data when database files are lost, stolen or read directly from media. New in Database 19c is the ability to encrypt the data dictionary, protecting sensitive metadata.
- **Dynamic Data Masking** with Oracle Data Redaction helps protect sensitive data in production applications by enforcing controls inside the database that redact data before it is returned to the application. It effectively hides the true values of sensitive data in a way that is transparent to applications, delivering (for example) just the last few digits of social security or bank account numbers. By defining and enforcing data redaction policies in the database, and not the application, customers can effectively protect sensitive data without changing their applications.
- **Privilege Analysis** records the use of privileges and roles in order to help remove unneeded privileges that unnecessarily expand the risk of a compromised database account. With Privilege Analysis, our customers can implement least-privilege access policies without compromising business operations. New this year is the transition of Privilege Analysis from an extra-cost feature of Database Vault to a core Enterprise Edition database feature.
- **Database Vault** provides separation-of-duties and trusted-path access models that further reduce the risk of compromised database accounts. With Database Vault, security administrators create policies that block administrator accounts from access to application data. Trusted-path policies further lock down application service accounts so that they may only be used within the normal context of the application infrastructure - a stolen or breached application account can't be used from a different location or with a different program. New in Oracle Database 19c is Database Vault Operations Control, designed to simplify security for Multi-Tenant databases by protecting pluggable databases from access via the container.
- **Unified Audit** offers customers an auditing architecture that is both policy-based and context-aware, complete with roles for managing auditing policies (e.g. based on factors such as time of day, IP address, program name, and proxy user name) and the viewing of audit data. Oracle Audit

*Vault and Database Firewall collects audit data from systems and databases both on-premises and in the cloud, providing a secure retention policy and compliance reporting. The Database Firewall provides a first line of defense with both detective and preventive controls for monitoring and blocking unauthorized SQL traffic before it reaches the database. Database Firewall employs a sophisticated SQL grammar analysis engine that inspects SQL statements going to the database and determines with high accuracy whether to allow, log, alert, substitute, or block the SQL, making it an effective control for detecting and blocking SQL injection attacks.*

- **Active Directory Integration** with Oracle Database 19c is greatly simplified with Centrally Managed Users. This feature directly connects the database to Microsoft Active Directory for authentication and authorization of users, eliminating the need to connect via Oracle Directory Services (which was required prior to Oracle Database 18c). Centrally Managed Users significantly reduces the complexity of managing authentication and authorization, while also improving user security and availability enterprise-wide.
- **Management of Encryption Keys** certificates, wallets, and credentials has become a vital part of organization's security ecosystem. Oracle Key Vault is a secure key management platform that helps facilitate the deployment of encryption throughout the enterprise, both on-premises and in the Cloud. It enables customers to centrally manage encryption keys, Oracle Wallets, Java Keystores, and credential files. Oracle Key Vault includes a browser-based management console for administration tasks such as provisioning server endpoints, securely managing key groups, and reporting on access to keys.
- **Removing risk from non-production database copies** is key to minimizing the amount of stored sensitive data and reducing the risk of data breach. Oracle Data Masking and Subsetting helps customers improve security, accelerate compliance, and reduce IT costs by sanitizing copies of production databases for nonproduction usage. It enables entire copies, or subsets, of enterprise data to be extracted from production databases and obfuscated while preserving referential integrity for development, testing and other purposes. Masking and subsetting of data is fully supported on-premises, on Oracle Cloud and for copying databases between both environments.
- **Assessing your Database Configuration** is an essential part of your security program, and the Database Security Assessment Tool (DBSAT) helps customers identify areas where their Oracle databases may be at risk and recommends changes and controls to mitigate those risks. New this year are enhanced DBSAT configuration checks that cross reference findings with the EU GDPR as well as widely used security standards like the Center for Information Security (CIS) Benchmarks and the US Defense Information Security Agency (DISA) Secure Technical Implementation Guides (STIGs). Also new this year is the DBSAT Sensitive Data Discovery module, which allows our customers to quickly find the location, type, and quantity of sensitive data contained in their databases, and provides actionable reports with prioritized recommendations to quickly address potential vulnerabilities.

## DATA WAREHOUSING AND BIG DATA

Oracle Database 19c provides customers with industry-leading performance, reliability and security for both transactional and analytic workloads, that can easily scale to meet the most demanding requirements whether deployed on-premises or in the Cloud. From an analytics perspective, Oracle Database 19c includes a wide range of optimizations such as analytic views, query approximations, and in-memory property graph analytics that can help customers efficiently measure business performance and perform predictive analytics. Oracle Database 19c is a multi-model database that provides full support for relational data and non-relational data, such as JSON, XML, text, spatial, and graph data. This enables customers to take full advantage of the performance, reliability, and security capabilities of Oracle Database, 19c to easily manage and integrate non-relational data into business applications, while eliminating the need for multiple specialty-databases (e.g. JSON and XML Databases). In addition, Oracle Database enables SQL access to non-relational data (e.g. JSON and XML) using SQL extensions or native APIs. It also supports a wide range of business intelligence tools for analyzing enterprise and other data sources on-premises or in the Cloud, including Oracle's Autonomous Data Warehouse Cloud.

### ORACLE BIG DATA PLATFORM

Oracle recognizes that enterprise data may be stored in disparate data stores (relational, Hadoop, NoSQL), on different platforms (general purpose hardware, engineered systems), and in various locations (on-premises, in-Cloud). In order to help customers evolve their traditional data warehouses and embrace the opportunity of big data, Oracle offers customers a Big Data Platform that provides integrated access to data stored in Oracle Database, Hadoop and NoSQL. The Oracle Big Data Platform can run on general purpose or engineered systems (e.g. Oracle Exadata and Big Data Appliance), be deployed on-premises and/or Oracle Cloud, and be accessed using a familiar SQL interface and familiar development and analytics tools. It effectively eliminates the need to move large volumes of data between disparate data stores, and customers can easily perform different types of analysis (e.g. Machine Learning, Graph, Spark), using different languages (e.g. SQL, REST, R), against different types of data (e.g. relational, XML, JSON), stored in different repositories (e.g. Oracle Database, Hadoop, NoSQL).

### HYBRID PARTITIONED TABLES

Breaking larger tables into smaller chunks or partitions makes them easier to manage and can improve performance by focusing operations on only the pieces of data they would be applicable to. Oracle Database 19c supports multiple models for partitioning data as well as online operations for partition management. However, as enterprise data continues to inextricably increase in size and complexity and regulatory requirements mandate that it is always online, a new model is required. With Hybrid Partitioned Tables, new in Oracle Database 19c, DBAs can now break data into manageable partitions as before, however DBAs can now select which partitions should be held in the database for fast querying and updating, and which partitions can be made read only and stored in external partitions. These external partitions can be held on on-premises in standard file systems or HDFS. DBAs can also choose to place the data in cloud-based object stores, thereby 'stretching' tables to the cloud.

### FAST SQL ACCESS FOR RELATIONAL, HADOOP AND NOSQL

Oracle Big Data SQL is the data-virtualization component of Oracle's Big Data Platform. It enables customers to use Oracle SQL for querying and analyzing data across Hadoop, NoSQL and Oracle Database, using their existing SQL tools, resources and skills. Big Data SQL delivers high-performance queries using Oracle's Smart Scan capability, first developed on Oracle Exadata, to execute SQL operations such as query filtering, joins and scoring, on Hadoop and/or NoSQL servers. Other key performance features of Big Data SQL include massively parallel, distributed query



processing and storage indexing. Oracle Big Data SQL also provides centralized metadata (via external tables) for simple access to data regardless where it is stored. Based upon this metadata, organizations can implement standard security policies, and apply Oracle Database security features such as data redaction and access controls, across data stored in Hadoop and NoSQL data stores.

#### COMPREHENSIVE ANALYTIC AND DATA SCIENCE CAPABILITIES

Oracle's philosophy is to move analytics to the data, and Oracle Database 19c offers developers and data scientists a choice of in-database analytics and APIs that can provide more in-depth business analysis. These include:

- **Analytic Views** that embed joins, aggregation rules, hierarchical metadata, and complex measure calculations into a single view that can be queried with any SQL tool. The calculation and aggregation rules are handled by the analytic view (not the SQL statement) enabling an easy-to-traverse representation of business data using simple SQL statements.
- **Approximate Queries** are a new class of data analysis including; `APPROX_COUNT_DISTINCT()`, `APPROX_COUNT()`, `APPROX_SUM()` and `APPROX_RANK()`, that can quickly return approximate answers, with a high degree of accuracy, without requiring excessive resource utilization.
- **Machine Learning and Advanced Analytics** delivers parallelized implementations of 30+ machine learning algorithms that “move the algorithms; not the data” for in-database processing, that accelerate the time from raw data to insights and predictions and faster deployment of predictive models throughout the enterprise.
- **Polymorphic Table Functions** a feature that enables the shape of data to be returned from a function by parameters passed which enable table functions to be more generic in nature.
- **Pattern Matching** enables pattern detection, in a sequence of events, stored in a database table using SQL syntax.
- **Machine Learning** with massively scalable in-database R processing and Spark algorithms that extend and enhance SparkML
- **Property Graph** with over 40 in-memory parallel algorithms that enable Oracle Database 19c to be used as a Graph database using simple standard interfaces.
- **Spatial** with over 50 functions for massively scalable Vector and Raster processing that enable seamless integration of spatial data with analytic and other applications.

#### BIG DATA CLOUD SERVICE

By integrating software and hardware components together at the factory with engineered systems such as Oracle Exadata and Big Data Appliance, Oracle helps organizations eliminate risk, optimize performance and speed time-to-implementation for their big data projects on-premises. Oracle also brings these same benefits to the cloud with the Big Data Cloud Service. It offers customers a comprehensive, high-performance service for Hadoop, Spark, and NoSQL and includes; Cloudera Enterprise Data Hub, R and Property Graph analytics, and data integration tools. Customers can start small with a 3-node cluster and easily scale out to 100's of nodes as required. Oracle Cloud not only delivers all of the capabilities of Oracle's on-premises solution, it also transforms Big Data deployments from on-premises upfront capital expenditure to a pay-as-you-go operational expenditure model.. Oracle's hybrid strategy of delivering the same architecture and software on Oracle Cloud as on-premises enables organizations to move to the cloud, while maintaining their existing skillsets, applications, and support resources for the Oracle Big Data Platform. Customers have the choice of deploying Oracle Exadata and Big Data Appliance for their data warehouse and big data systems on-

premises, or consuming Exadata and Big Data Services in the Oracle Cloud

## AUTONOMOUS DATA WAREHOUSE

Oracle recently introduced the Autonomous Data Warehouse, a unique service that offers customers enterprise performance, reliability and security for their data warehouses, data marts and data lakes, with no administration support required. The Autonomous Data Warehouse is an easy to use service (e.g. it does not require manual intervention normally associated with data warehousing on-premises), it's fast (e.g. it runs on Oracle Exadata) and it's completely elastic (e.g. customers can independently scale compute and storage with zero downtime). The Autonomous Data Warehouse offers customers complete analytic freedom, with a choice of interfaces (e.g. SQL and APIs), analytic services (e.g. Machine Learning and Graph, and data management services (e.g. Autonomous Cloud and Object Stores). Therefore, customers have the ability to easily collect data from object stores in the Autonomous Data Warehouse, or easily connect to data resident in object stores for analytical purposes.



Figure 2. Analytic Freedom with Autonomous Data Warehouse

## APPLICATION DEVELOPMENT

Oracle Database 19c not only offers customers the latest generation of the world's most popular database, it also offers developers an integrated data management solution that is supported by all popular application development frameworks in use today. This enables developers to quickly build applications that can easily take full advantage of the performance, reliability, security, and other features of Oracle Database 19c, thereby protecting customer's investments in existing development resources and skill sets.

### APPLICATION DEVELOPER FRAMEWORKS

Oracle Database offers developers native programmatic interfaces as well as support for a wide range of development and scripting languages including:

- *SQL and PL/SQL*
- *Oracle Call Interface*
- *Programming languages including Java, C and C++*



- *Scripting languages including PHP, Ruby and Perl*
- *.NET with Oracle Developer Tools for Visual Studio, Oracle Data Provider for .NET and Oracle Database Extensions for .NET.*

## ORACLE APPLICATION EXPRESS

Oracle Application Express (APEX) is a database-centric rapid web application development tool for building a vast array of applications. It's included with every on-premises edition of Oracle Database and every Oracle Database Cloud Service. APEX is completely declarative, and, using only a web browser, end users and experienced developers can quickly build and deploy fast, reliable and secure database applications. It's ideally suited to power users writing reports or simple forms to experienced SQL and PL/SQL developers implementing sophisticated applications for business operations.

## ORACLE SQL DEVELOPER

Oracle SQL Developer simplifies the development and management of Oracle databases – including pluggable databases. It's also included with every on-premises edition of Oracle Database and every Oracle Database Cloud Service. SQL Developer offers complete end-to-end development of PL/SQL applications, a worksheet for running queries and scripts, a DBA console for managing the database, a reports interface, a complete data modeling solution, and also a migration platform for moving non-Oracle databases to Oracle Database 19c.

## ORACLE REST DATA SERVICES

Oracle REST Data Services (ORDS) is a mid-tier technology that serves up RESTful Services for Oracle Database. ORDS enables developers to transform Oracle Database into an easy-to-use RESTful API Service. ORDS receives REST requests and marshalls those to Oracle Database as SQL or PL/SQL code blocks, returning any output as a JSON collection back to the calling application. With ORDS, any database resource can be made available via REST, and the data access APIs can fully exploit all the power of Oracle Database for the highest performance, reliability and security.

## JSON SUPPORT

Oracle Database offers full support for storing, querying and processing of JSON data, enabling developers to utilize Oracle as a NoSQL database using the Simple Oracle Document Access (SODA) API, REST or JAVA NoSQL APIs to build applications. It includes a number of functions that return or manipulate JSON inside the database via SQL, and JSON data may also be easily queried for analytical reporting using SQL and SQL generating tools.

## ORACLE LIVESQL

[Live SQL](#) provides the Oracle database community with a simple online way to test and share SQL and PL/SQL application development concepts, tutorials and practices. No on-premises or in-Cloud database hardware or software, installation or configuration is required. Only a web browser is required to access sample SQL and PL/SQL scripts running on Oracle Database 19c that may be freely created, copied, tested and shared as required.

## ORACLE DATABASE ON DOCKER

Oracle Database (single instance and RAC configurations) and related developer tools are available in the Docker Store marketplace via the Docker Certification Program, a framework for vendors like Oracle to integrate and certify their technology to the Docker platform. Developers can therefore pull images of Oracle Database in Docker and quickly start developing, testing and deploying modern enterprise applications, using Docker Enterprise Edition as their container platform.

## CONCLUSION

The latest generation of the world's most popular database, Oracle Database 19c, builds upon key architectural, performance and distributed data innovations successfully established in Oracle Database 12c and 18c releases. Its unique multitenant architecture, dual-format in-memory column store and native sharding features have enabled customers to evolve their databases, both on premises and in the Cloud, to meet their business and cost control objectives.

Oracle Database 19c now provides customers with a high-performance, reliable and secure platform to easily and cost-effectively modernize their transactional and analytical workloads either in the Cloud, or on-premises, or in a Hybrid Cloud configuration. It offers the same familiar database software running on-premises and in the Cloud that enables customers to take their in-house developed Oracle applications and ISV applications and run them on Oracle Cloud without incurring any application changes. Customers can therefore continue to utilize all their existing IT skills and resources, and get the same support for their Oracle Databases both on-premises and in Oracle Cloud.

Unique, critical database capabilities such as Real Application Clusters and Active Data Guard, and unique Engineered Systems such as Oracle Exadata and Database Appliance, have helped establish Oracle as the database market leader by a wide margin. Indeed, Oracle has been widely proven to provide the performance, reliability and security required for some of the world's most demanding operational and analytical workloads. Oracle Database 19c takes the management of customer's enterprise data to the next level, helping customers on their journey to the cloud.

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## Integrated Cloud Applications & Platform Services

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