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Modernize IT Infrastructure: Oracle Mainframe Migration

August, 2023 Version 5.0

Public

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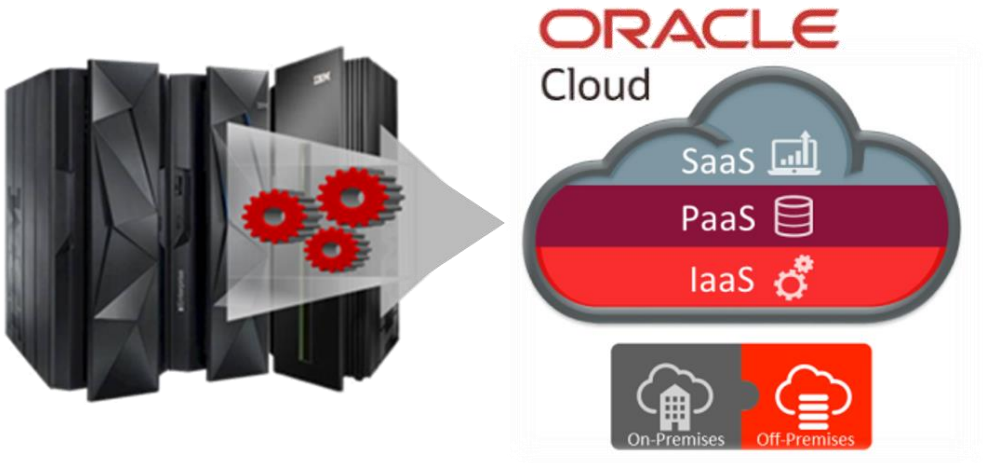


Oracle provides the most complete solution for migrating mainframe applications and data intact to on-premises open systems or to the Cloud without losing business value or sacrificing Quality of Service. The result – customers reduce or eliminate mainframe costs, contain MIPS, and accelerate legacy modernization.

Introduction

Rapid changes in today's global business environment drive organizations to reduce the cost of their IT infrastructure and operations, improve their ability to react to changing business demands, and minimize reliance on legacy systems and retiring mainframe skills—all while improving competitiveness and business alignment.

Companies and government organizations face increasing pressure to deliver more business value and better services from their IT spending and free up funding for new initiatives. In this environment reducing mainframe costs and modernizing legacy applications have become top-of-mind concerns for CIOs and CFOs alike. Business-critical mainframe applications are invaluable assets; their embedded business logic representing years of development and evolution. Among large enterprises, these assets represent 60% - 70% of all business-critical applications consuming two-thirds of IT's operations budget. Migrating these applications from mainframes to open systems can dramatically reduce the infrastructure and operations cost and unlock the business logic for faster integration and evolution.

Three key success factors emerge from Oracle's numerous mainframe rehosting customers:

- Leveraging automation and proven migration practices to reduce project duration, cost, and risk, accelerating savings and demonstrating business value within a year or two
- Providing compatibility with COBOL & C/C++ and online & batch mainframe programming models to preserve the application investment in business logic and valuable data. The intact migration minimizes change, reduces testing effort, and avoids user re-training and business process impact.
- Architecting an open system target environment to meet mainframe-grade Quality of Service (QoS) requirements – to ensure that migrated applications continue to meet performance and availability SLAs

Facts:

- 5 trillion dollars a day in global inter-bank settlement transactions
- €110B in annual healthcare reimbursement payments in France
- 2.6M S.W.I.F.T. payment messages an hour in the UK
- 50B annual credit card transactions in China
- 150M daily logistics transactions in US
- 2M US government benefit transactions an hour
- 56K mobile billing transactions per second in Japan

One system. Oracle Tuxedo.

Meeting these challenges requires a uniquely powerful solution that supports mainframe applications and their programming models through compatible online and batch runtimes, while running on an application platform that delivers proven, mainframe-grade QoS on open systems, whether on-premises or in the cloud. It must also:

- Enable automated re-hosting of application code and data for faster and low-risk migration
- Run on a distributed infrastructure for horizontal scalability and fault-tolerance, either on premises, in the cloud, or with hybrid topology, and provide automatic scaleout and elasticity as well as Disaster Recovery for mission-critical applications
- Retain connectivity and interoperability with remaining mainframe systems and applications for parallel operation or to support phased migrations, ensuring data consistency and integrity between the two environments
- Enable rapid integration and extension of rehosted applications via standards-based and legacy protocols; COBOL, C/C++, Java, Javascript modules, and Microservices.

Oracle Delivers for Mainframe Customers

While some organizations delay because of risk concerns, Oracle customers have embarked on this modernization journey with confidence.

Unique in the mainframe migration space, Oracle's re-hosting solution leverages the mainstream foundation of leading software platforms: Oracle Tuxedo and Oracle Database, running business-critical applications at tens of thousands of large customers. These custom and packaged systems are used daily by millions of people for core banking and payment services, funds transfer, travel reservations, telco billing, logistics, and ERP (e.g., PeopleSoft.) The robust foundation of Oracle Database and Oracle Tuxedo deployed in Oracle's Maximum Availability Architecture (MAA) ensures mainframe-grade availability and performance.

The evidence is in: proven five 9's of availability in many customer production environments delivering business-critical financial services, mobile billing, managing reservations, and handling government benefits. A number of these applications run at tens of thousands of transactions per second (tps), and in some customer benchmarks Oracle Tuxedo and Oracle Database/RAC exceeded 100,000 tps.

For mainframe customers considering migration, this provides the confidence of using proven foundation systems with Oracle's global support, services, and R&D investment. Customers who have already migrated to open systems have experienced mainframe-class reliability and performance and have gained additional scalability and flexibility at a fraction of the mainframe cost.

In addition to the mainframe-class availability and performance, Oracle's solution is uniquely open and flexible – it runs on a number of hardware/OS platforms, either on-premises or in a cloud, supports multiple COBOL compilers, enables use of multiple languages for new extensions (e.g., COBOL, C/C++, Java, Javascript), integrates with JEE, Spring Boot, and .Net, and supports Web Services APIs, etc. to help align with customer's enterprise standards. This simplifies the evolution and modernization of the migrated applications and promotes additional budget efficiency and choice long after the initial migration.

Customers Cut Costs, Gain Flexibility

At one utility company, migration of customer care and billing applications from IBM CICS/DB2 environment to Oracle Tuxedo and RAC has resulted in shutting down 14 mainframe processors, while enabling a 300x increase in the volume of data traffic and processing required to support new modes of client interaction. This level of scalability wasn't affordable with mainframe OLTP and database processing. As the result of the migration, the customer experienced an approximate 25% performance gain in online and batch processing and was able to take advantage of a cost-effective, scalable architecture provided by Oracle RAC Database and Tuxedo-powered application grid. Leveraging a portion of $5M/year in savings from decommissioning the mainframe has also enabled them to deploy active/active disaster recovery capabilities for business continuity.

Another customer has replaced 12,000 MIPS of mainframe capacity with Oracle Database and Tuxedo infrastructure on UNIX servers, in the process reducing their annual cost from $65M to $10M. This customer is handling health insurance services in France for over 50M members and supports over 80,000 portal users, generating over €110B/year in reimbursement payments. Migrating data and applications from disparate mainframe environments to an Oracle open systems stack enabled them to extend the functionality with a component-based approach. The extensibility of Oracle Tuxedo with Oracle Fusion Middleware solutions enabled more agile response to frequent regulatory changes, and enabled them to add claim processing services for other government agencies.

A large North American telco turned to rehosting after attempting to reduce their 6000 MIPS mainframe footprint through Java conversion projects for some legacy CICS, IMS, and batch applications, which didn't lead to satisfactory results. With four rehosted applications already in production, the next phase of the project will tackle a larger subset of their many candidate applications. A phased migration, such as this, depends critically on robust integration capabilities to run a hybrid environment – and the Oracle Tuxedo platform running rehosted CICS and IMS applications along with rehosted batch jobs delivered a rich set of integration options for:

- Windows and JEE front end applications
- MQ and Web Services integrations
- Mainframe resources including CICS and IMS transactions, DB2 and IMS DB data, and RACF authentication

A global car company in Japan has migrated their batch cost accounting system to Tuxedo ART using the batch runtime for JCL/COBOL production support, and also modernized some 4GL programs by recoding in Java. They've also modernized the rehosted batch jobs by adapting provided templates for auto-generation for ease of adding future jobs, using database-backed file catalog for managing GDG files, and parallelizing batch streams over distributed nodes to shorten the batch elapsed time.

A 100+ year old insurance company in Italy with more than 4.5 million policyholders has migrated their 4000 MIPS IBM z/OS mainframe to Oracle Tuxedo and Database in three phases. An initial 5 month phase migrated high CPU consuming CICS transactions to Tuxedo ART for CICS, while retaining interoperability with the rest of CICS transactions and mainframe data using Tuxedo Mainframe Adapter and DB2 Connect, resulting in an immediate 1200 MIPS reduction and substantial immediate cost savings. Subsequent two phases migrated the rest of CICS transactions and batch jobs off the mainframe, resulting in decommissioning the entire mainframe estate.

Simplifying and Accelerating Migration

Combining the support for CICS, IMS, and batch programming models and functions, with Tuxedo Application Rehosting Workbench, which provides tooling and methodology for automating the migration life-cycle, simplifies and speeds up the re-hosting process. Oracle's solution supports CICS and IMS programming APIs and services, batch JCL functions and utilities, and helps to migrate VSAM/flat file/DB2 data, as well as provide remote access to DB2 and IMS DB on z/OS. This enables customers to keep application logic and data intact, while moving them to Oracle Tuxedo, the #1 application server for C/C++ and COBOL traditional and enterprise cloud deployments with mainframe-grade RASP.

The application runtimes leverage distributed Tuxedo foundation for:

- Fault-tolerant application grid foundation on open systems delivering five 9's availability through health and service level monitoring, autonomous recovery and fail-over
- Multi-language services with COBOL, C/C++, Java, Javascript, Python, etc. with rich integration options and gateways
- XA-compliant distributed transactions (i.e., 2PC or SYNC Level 2)
- Robust workload management with dynamic load balancing, priority management, and distributed resource management using Virtual Machines or Kubernetes containers
- Strong performance optimizations delivering substantial performance gains
- Cloud deployment using OCI Tuxedo images – delivers rapid provisioning, horizontal scale-out, and integrated end-to-end monitoring and management

On top of this foundation the Oracle solution provides Application Runtimes for CICS, IMS, and Batch to support the required programming models and services. However, a complete migration project goes beyond the APIs and related functions. Oracle's solution caters to the full migration lifecycle and provides automated tools to support it.

Tuxedo Application Rehosting (ART) Workbench

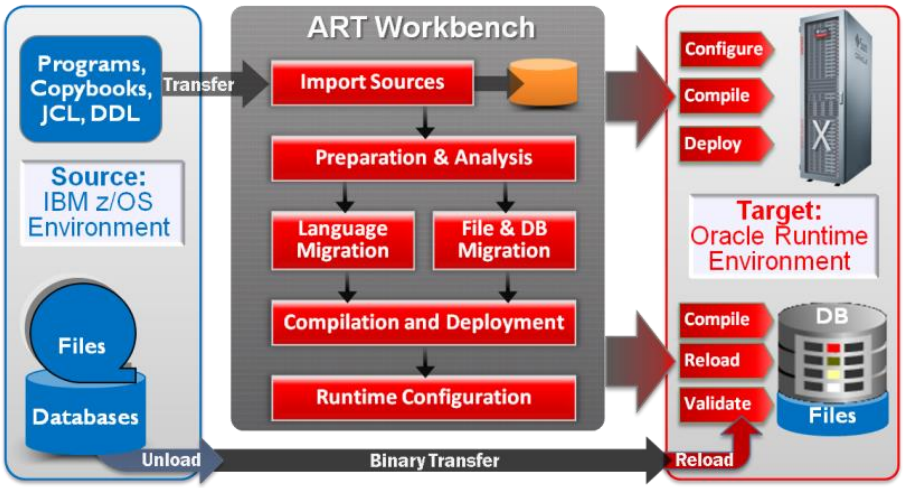
The Workbench provides complete lifecycle support from importing the source code to analyzing the entire code base, automatically migrating code as required, and automatically creating deployment configuration and data re-loading scripts for running re-hosted applications in the Tuxedo domain.

The Workbench provides a GUI and a CLI, which integrate the collection of tools in a guided, industrialized migration lifecycle. After importing the application's source assets, the Workbench catalogs COBOL (CICS / IMS / Batch), BMS/MFS, JCL, and DB2 DDL components, validates all cross-dependencies generating anomaly reports (e.g., missing components), creates an internal representation of these assets, and creates a file migration mapping from COBOL and JCL file references.

Based on this analysis and configuration settings, the migration tools adapt COBOL components between compiler dialects, transform embedded DB2 SQL to Oracle SQL, optionally convert JCL to batch job scripts (or customers can retain native JCL and execute it directly in the batch runtime), convert DB2 DDL and VSAM Copybooks to Oracle Database schemas (or keep VSAM files as is), and generate tools for automated bulk data migration. The unique capabilities of the workbench simplify data migration, even supporting migration VSAM files to relational database tables, while allowing the online and batch applications to retain VSAM data access logic and the relevant APIs.

CICS and IMS applications also depend on specialized resources defined in CICS CSD and IMS DBDGEN and PSBGEN processes. The Workbench automatically converts these resource definitions into Tuxedo ART formats as part of the Convert phase in the migration lifecycle, simplifying the runtime configuration.

Figure 1. Automating Mainframe Migration Process and Managing Project Lifecycle



Following the migration of the programs and data, the Workbench facilitates the configuration of the runtimes and build process for compiling application programs and WB-generated technical components. This includes configuring CICS, DB2, Oracle pre-compilers and COBOL/C compilers, then running the full build process using the generated artifacts. The generated build process can be integrated into fully automated CI/CD pipelines.

Finally, a Deploy phase in the lifecycle handles the packaging and deployment of the migrated application and all the related components, as well as reloading files and database tables using generated transcode/reload tools with the extracted mainframe data. Once completed, the "Run" menu option can now be used to start any of the three runtimes and begin testing CICS/IMS transactions and batch jobs.

While many customers migrate the data along with applications, partial or phased migrations may require shared access from migrated and mainframe applications. Oracle's solution can remotely access z/OS databases using DB2 Connect for DB2 and ODBA Proxy for IMS DB, or synchronize data between Oracle Database and mainframe DB2 using Oracle GoldenGate. In addition, Oracle Database Gateways provide the ability to transparently access data residing in DB2 on z/OS from an Oracle Database environment.

As a result of its high precision, uniform rule-based transformations and effective automation, the Workbench enables an industrialized migration approach, which has provided high efficiency and productivity in migrating very large mainframe applications with tens of millions of lines of code. Migration projects using the Workbench had lower overall project risk profiles, and resulted in much faster project delivery at lower cost.

Autonomous Oracle Database on Exadata Database Machine

Oracle Database underpins many of the mainframe migration projects done by Oracle and our competitors. With the Oracle migration solution, the Workbench automates both DB2 schema mapping to Oracle, and generation of the required data extraction/transform/re-load tools (including extract JCL, converters, and SQL*Loader scripts) to migrate and validate the data in Oracle automatically. It similarly automates the migration process from VSAM datasets to Oracle tables, generating an additional data mapping layer that preserves VSAM access code in the online and batch programs, while translating it to SQL access to the Oracle Database. Additionally, partner solutions provide similar migration and data mapping layer for IMS DB migration to Oracle.

Migrating to Oracle Database using the latest generation of Autonomous Database deployed on Exadata Database Machine (available in Cloud and on-premises) provides the most advanced capabilities in hardware and software:

- Exadata advantages
  - Advanced hardware: fully scale-out servers and intelligent storage with unified RDMA Network Fabric connectivity and PCI flash with Persistent Memory Acceleration
  - Advanced software: Database optimized compute, storage, and networking algorithms dramatically improve performance and cost
- Autonomous Database advantages
  - **Self-driving:** Provisions highly available databases, configures and tunes for specific workloads, and scales compute resources when needed, all done automatically.
  - **Self-securing:** Protect sensitive and regulated data automatically, patch your database for security vulnerabilities, and prevent unauthorized access.
  - **Self-repairing:** Detect and protect from system failures and user errors automatically and provide failover to standby databases with zero data loss.

Customers have multiple deployment options, including:

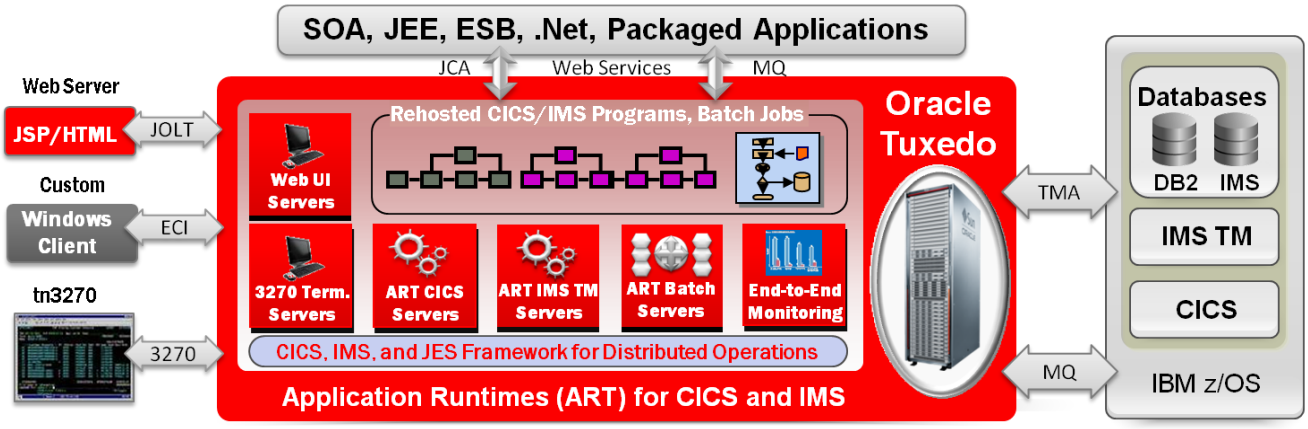
- Exadata Cloud Service (ExaCS) in OCI using dedicated or shared resources in OCI public, dedicated, or sovereign regions, which enables elasticity and enables databases to run faster and with fewer resources on scale-out Exadata infrastructure that includes unique optimizations for transaction processing, analytics, and mixed workloads. Online scaling of compute resources enables customers to quickly adjust consumption to match workload needs without interrupting operations while efficient consolidation lowers total costs.
- Exadata Cloud@Customer (ExaCC), which enables you to apply the combined power of Exadata and Oracle Cloud inside your own data center. You have full access to the features and operations available with Oracle Database, but with Oracle owning and managing the Exadata infrastructure.
- Exadata Machine on-premises, which enables customers to meet the needs of growing on-premises workloads with the highest performance, scale, and availability.

Tuxedo Application Runtime for CICS

Tuxedo provides runtimes that emulate mainframe programming models. This serves as the target environment for rehosting CICS applications from IBM z/OS to open systems delivering support for the EXEC CICS programming model in COBOL and C/C++ and the transactional, messaging, queueing, data access, program control, tn3270 handling, Web support, and other services and integrations required by the API. It includes support for synchronous and asynchronous transactions, DPL programs, conversational and pseudo-conversational programs, TS and TD queues, 3270 BMS services, VSAM and database (DB2, IMS, and Oracle) access, integrations support for WMQ, Socket Listener, HTTP/S, Web Services, ECI, and CPI-C/APPC communications, and global transaction coordination/recovery.

Users connecting to CICS applications via traditional tn3270 emulators or clients based on CICS ECI or CPI-C/APPC protocols can continue using these connections after migration – the integrations are built-in as part of the CICS runtime to avoid any impact on the users. In addition, customers can eliminate the cost of tn3270 emulator licenses and replace them with just a Web browser leveraging Web UI integration and identical JSP/HTML screens converted from 3270 BMS using one time conversion service offered by Oracle partners.

Figure 2. Tuxedo Runtime Services for CICS, IMS, and Batch Mainframe Applications with Broad Integration Options



Many CICS workloads are messaging-driven, and the Oracle Tuxedo solution provides standard integration options, including its JCA adapter to replace IBM CTG in JEE app servers, support for Web Services, HTTP, Socket Listener, or MQ-initiated transactions, and mainframe CICS connectivity using APPC/DTP or DPL over Tuxedo Mainframe Adapters (TMA). In addition, CICS transactions and DPL programs can leverage configuration-based integration with other Tuxedo services (in Java, COBOL, and C/C++), Oracle Service Bus (OSB), and other standards-based services and gateways with no coding changes.

The runtime leverages underlying Tuxedo infrastructure for CICS MRO configurations. Customers benefit from a fully-distributed deployment model using a horizontally scalable cluster of traditional servers, Oracle Engineered Systems like Oracle Private Cloud Appliance (PCA), which integrate compute nodes, storage, and network fabric in a single system, or a private or public Cloud using containerized deployments managed by Kubernetes. Centralized monitoring and resource management for such CICSPlex-like environments is provided out-of-the-box by Tuxedo System and Application Monitor (TSAM) Plus and Oracle Enterprise Manager (OEM). These tools can support rapid provisioning and elastic scale-out of CICS regions on-request or based on pre-defined load criteria.

Tuxedo Application Runtime for IMS

The target environment for re-hosting IMS applications to open systems supports the IMS online and batch programming models and DLI APIs in COBOL and C/C++. It includes support for MPP regions with multiple transaction types (response/non-response mode, conversational/non-conversational mode), tn3270 interface (with basic edit mode and MFS mode), and IMS batch support (BMP/DLI regions and DFSRRC00 utility to launch them.) IMS programs can access migrated GSAM files, IMS DB and DB2 data, or use remote access to the mainframe databases.

Similar to CICS runtime, user interface is provided through tn3270, or a Web browser using Web UI integration and partner services to convert 3270 MFS screens into JSP pages.

JCA adaptor for JEE connectivity and TMA for mainframe connectivity support message-driven integration requirements. When used with mainframe IMS TM regions, TMA supports APPC and OTMA for synchronous and asynchronous connections with full SYNC Level 2/2PC support. Re-hosted IMS transactions can also integrate with other Tuxedo services, Web Services, OSB, IBM MQ, and other Tuxedo-supported protocols.

Similarly to CICS runtime, IMS TM runtime fully leverages Tuxedo grid features for MSC configuration and distributed deployments across traditional servers, engineered systems, or in an enterprise cloud using Virtual Machines or Kubernetes-managed containers, with TSAM/OEM providing centralized monitoring and management capabilities.

Tuxedo Application Runtime for Batch

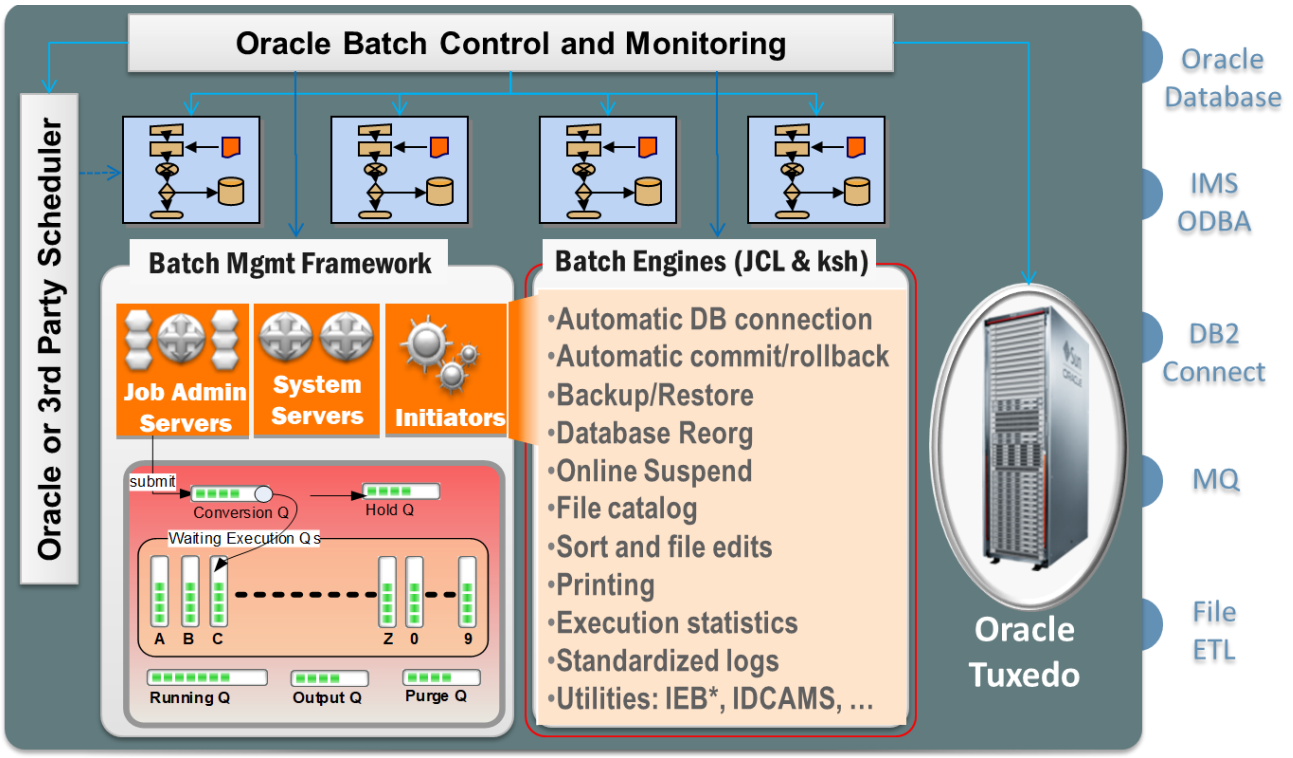
Batch jobs are critical in mainframe environments, and the Oracle solution provides robust support for rehosting JCL jobs and their programs, files, and databases without changing job flow or business logic. This runtime integrates JES-like production management capabilities with built-in JCL functions, standard utilities, and access to migrated and mainframe data in an open, extensible framework. This robust production environment can execute native IBM JCL or job script wrappers generated from JCL in Linux scripts by Oracle Tuxedo Application Rehosting Workbench.

The Batch runtime provides JES-like batch management using job queues defined in Tuxedo QSPACE and job control using standard job parameters (e.g., job name, class, priority, etc.) and job stages. Standard JES functions to submit, hold/release, cancel, purge, and query jobs cluster-wide are available through a command-line interface (CLI), open services API, ISPF extensions, and Web UI. The CLI and services API enable integration with any batch scheduler, including Oracle Database scheduler, as well as 3rd party enterprise schedulers, and, through agents, mainframe schedulers. The services API can be used via Web Services, JCA adapter, and other gateways to enable real-time job control from other enterprise applications. Users can perform centralized job control, view job status and logs, and manage the batch operations through ISPF panels or the Web UI provided by TSAM/OEM, which also features SLA management, log archiving, and reporting.

The jobs are processed through regular JES stages and queued by job class and priority until picked up by a Tuxedo initiator service that monitors queues based on its assigned job classes. The runtime distributes the workload in a batch grid by defining initiators on multiple nodes and provides mainframe-compatible file management and locking in a local filesystem and over NFS for shared file access from multiple batch nodes.

Once the job is launched, it leverages all the typical production functions provided by the batch execution environment, including automatic DB connection/disconnection, commit/rollback, file access with concurrency control based on DISP, support for GDG functions and file catalog for their metadata, a library of built-in utility functions, and conditional execution based on return codes.

Figure 3. Comprehensive Batch Control, Execution, and Monitoring Framework for Native JCL and Scripted Batch Jobs



This open batch environment can easily incorporate new steps or jobs using any 3GL or Java programs, COTS modules, native OS scripts or tools, integrate with any scheduler and leverage open system versions of the traditional mainframe 3rd party components (e.g., Syncsort DMX, LRS VPSX for printing). Re-hosted batch jobs can handle CICS and IMS integrations, including use of IMS BMP and CICS EXCI calls. Oracle data access or remote access on z/OS using DB2 Connect and IMS ODBA are available, as are integration and reporting options through Oracle Data Integration (ODI) services and Analytics/BI solutions for modernizing data extracts, transformations, and reporting.

Powered by the Tuxedo infrastructure, the batch runtime supports centralized job submission and control with distributed execution across multiple nodes, which enables batch workloads to use more resources and helps to parallelize batch execution whenever possible. Elastic scale-out of batch environments can be used to dynamically allocate resources in response to fluctuating workloads or SLA alerts.

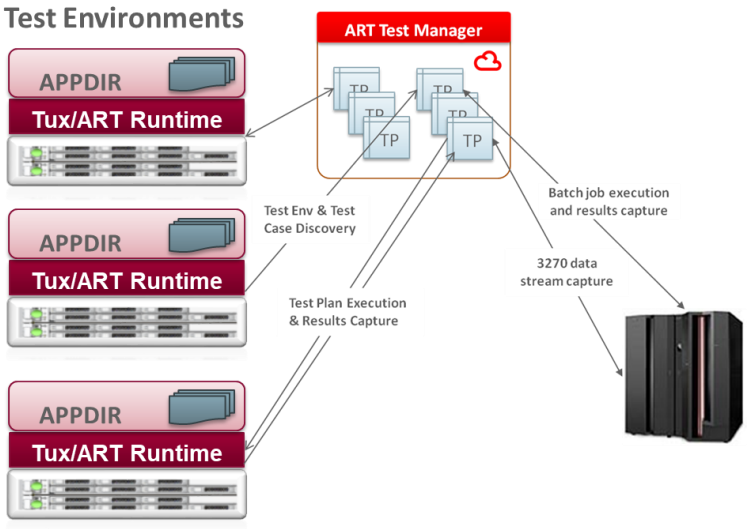
Tuxedo Application Rehosting Test Manager

Oracle Tuxedo Application Rehosting Test Manager (ART TM) helps to automate and speed up testing in mainframe re-hosting projects. Complementing Tuxedo ART Workbench, which provides tools for automating and speeding up the migration process, the Test Manager focuses on the remaining part of the rehosting project – testing the migrated applications and ensuring non-regression of their functionality. It helps customers to complete the application functional or regression testing faster and more efficiently, thus reducing overall project cost and speeding up time to value – when the target environment can be switched into production and expected savings from elimination or reduction of mainframe MIPS begin to accrue along with other benefits.

Identifying the scope of testing and defining a test plan, determining how to test the application and executing test scenarios can present a challenge when re-hosting older applications. To help customers address these challenges, ART TM can capture a lot of the information automatically – partly from the ART Workbench-generated application configuration and partly from capturing baseline test sequences and results from the mainframe execution. The application execution on the mainframe, in test or production environment, becomes the “source of truth” for expected behaviors and results in the re-hosted application.

A key benefit from ART TM’s capture of online and batch mainframe test scenarios is the ability to replay them on the target Tuxedo/ART environment, and then use captured mainframe results to compare with those generated on the target. Such baseline and results capture, preparation, test execution, and results compare are available for tn3270-driven online CICS and IMS transactions and API-driven remote CICS or IMS program execution. It is also available for batch jobs where the original job sequence can be recorded, replayed against Tuxedo ART Batch and the mainframe, and DB updates and file comparison enabled through ART TM. This can also be extended to use additional custom results compare scripts. Such automated comparison can help transfor the test effort from a manual, human-intensive task to an automated, industrialized process, which speeds up the evaluation of the test results and identification of potential issues.

Figure 4. Automated Test Generation, Execution, and Results Compare



ART Test Manager also provides centralized access to logs and trace files, and its status dashboard helps with results and status reporting. The test plans and automated test

cases can also become a part of the ongoing regression test capability as migrated applications continue to change through ongoing maintenance and business evolution.

Resilience and Supportability

Complex environments and applications do not always perform with 100% reliability, on or off the mainframe. When a problem happens, the underlying software must provide a degree of resilience to autonomously overcome certain issues and continue running. It must also provide sufficient diagnostic information to help support personnel rapidly identify the cause of the problem, so it can be resolved. Tuxedo provides both – a high degree of resiliency and availability, and strong diagnostic capabilities to help identify issues rapidly.

When connections to the external resources, such as database, MQ, or the mainframe back-end are lost, Tuxedo is designed to try to re-connect automatically and intelligently. When connections cannot be re-established, Tuxedo suspends affected servers and routes the work to other replicas that have functioning connectivity. Tuxedo also leverages advanced capabilities of the Oracle Database, such as Application Continuity, to mask temporary database disruptions or outages from end users and applications by recovering the in-flight work for impacted database sessions following outages. When enabled, Tuxedo will declare the database request boundaries to the database to enable the application continuity feature to replay database requests (transactions or queries) exactly as they were originally submitted, to ensure a result consistent with the request.

When a Tuxedo node (a VM or physical machine) fails, the cluster continues to operate and the work is routed to available Tuxedo resources without affecting users. This built-in fault tolerance is what allows Tuxedo customers to run non-stop operations for many years. When failed resources come back online, Tuxedo will re-configure itself to bring them back into operation. These same capabilities, in conjunction with Oracle Database RAC features, enable continuous operation despite any Tuxedo or RAC instance failures. Zero-downtime updates are supported as individual instances can be taken offline and then brought back online as needed without impacting customer applications or data access.

But sometimes applications fail; on the mainframe this is known as ABEND. Tuxedo runtimes provide tracing capabilities, and in conjunction with C/COBOL compilers, reverse-attach debugging and formatted dumps. Tuxedo can dynamically vary trace levels, enabling users to collect more trace data on demand. Each runtime also supports configurable debug settings to set up a reverse-attach to an interactive debugger when a certain transaction, program, or job starts executing.

Advanced call path monitoring features in TSAM enable deep analysis inside CICS and IMS transactions to determine all their touch points and get detailed timings for CICS verbs and IMS DLI calls, SQL database accesses, and MQ calls inside the transaction.

Leveraging Mainstream Platform

Customers leveraging a mainstream platform, like Oracle Tuxedo, benefit from its broad customer base and robust ongoing R&D investments in the Tuxedo product family, the rest of the Oracle Fusion Middleware, Oracle Database, Oracle Exadata, and public and private Oracle Cloud services. Tuxedo optimizations for engineered systems deliver dramatic performance gains for online and batch applications – up to 8X faster messaging, up to 5X throughput gain for database access.

Evolving and modernizing rehosted applications after the initial migration can provide additional value. Tuxedo enables a number of incremental modernizations, such as:

- Exposing migrated CICS and IMS transactions through Tuxedo services, Java interfaces, Web Services (SOAP or REST), and extending them to mobile APIs
- Extending the functionality of legacy systems through new components in COBOL, C/C++, Java, or other languages and through calls to Web Services in other applications
- UI transformation from tn3270 to Web UI and subsequent re-factoring
- Exploiting relational database benefits for VSAM and IMS DB migration, including 24x7 concurrent operations when VSAM files are migrated to Oracle, avoiding batch windows and ability to leverage of VSAM and IMS DB data in rich Analytics solutions

Oracle's investment in Oracle Cloud Infrastructure, on which Tuxedo is certified to run using Virtual Machines or Kubernetes containers, delivers direct benefit for customers migrating mainframe applications:

- Shifting spending from CAPEX to adjustable OPEX, with unlimited growth on demand
- Rapid provisioning and de-provisioning of specific environments (e.g., for QA, integration test, peak workloads, etc.)
- Dynamic scalability and elasticity using OCI Autoscaling and Kubernetes-managed containers
- Automated patching, backups, updates
- Integrated end-to-end monitoring & operations enabled by TSAM Plus and OEM across Oracle middleware and database stack
- Advanced Oracle Log Analytics to detect anomalies
- Applying advanced Analytics and Machine Learning capabilities to data previously locked in non-relational VSAM datasets or IMS databases after migrating to Oracle Database
- Oracle Cloud Infrastructure options supporting public, dedicated, sovereign regions around the world, and additionally providing Oracle Cloud in your datacenter, e.g., Cloud@Customer.

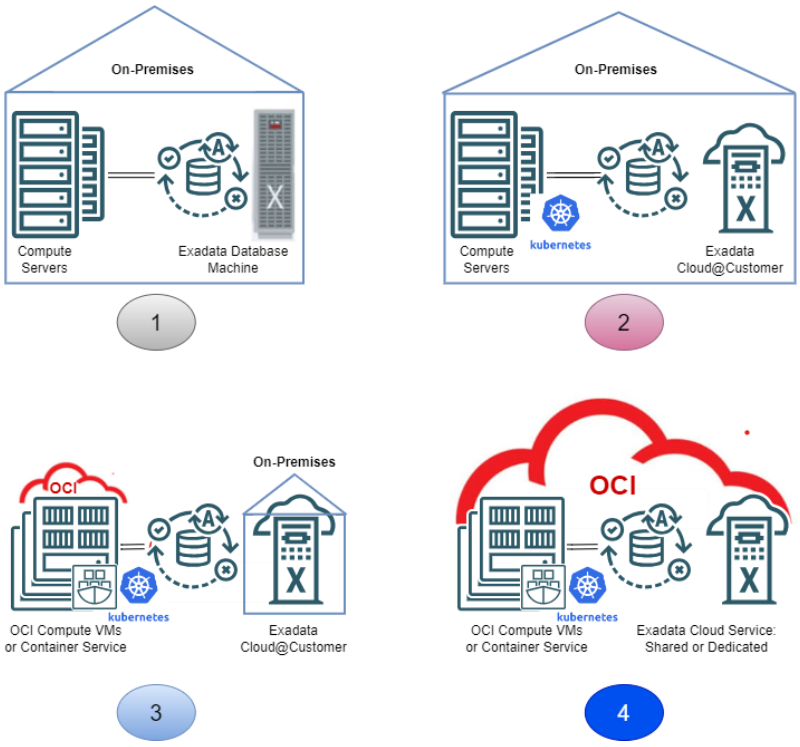
Deployment Flexibility with Oracle Cloud

Some customers migrate to cloud as part of their data center exit strategy, while others look to the cloud for more agile and cost-effective infrastructure. There are many options, but few protect your investment in the application's business logic and data. Oracle's mainframe migration not only achieves this, but enables you to choose the degree of "cloudification" you are ready for at any point in your migration journey. All migrations to open systems will separate the monolithic mainframe environment into application tier and data tier, which can be deployed and scaled separately. As shown in the diagram below, Oracle can provide four target deployment architectures for your migrated mainframe:

1. **On-premises.** This allows you to deploy the application tier on your existing or new compute servers and Oracle Database on Exadata Database Machine under your control. This allows you to consolidate any existing and migrated databases and run them with the highest performance, scale, and availability. Your application tier can be deployed on VMs or Kubernetes-managed containers.

2. **Cloud@Customer.** This retains the application tier on your compute servers as above, but places the data tier on the Oracle-managed Exadata Cloud@Customer option that allows you to automate database operations by using Exadata Cloud Service and Oracle Autonomous Database in their data centers. Managed by Oracle and secured behind your firewalls, Exadata Cloud@Customer allows customers with data sovereignty, security, or latency requirements to start using Oracle's most advanced cloud database and cloud automation technologies using a subscription based pricing model and Oracle Cloud managed services.

Figure 5. Flexible Deployment Architectures Enable Gradual Move to Cloud



3. **Hybrid.** Run the application tier on Oracle Cloud Infrastructure in a public, sovereign, or dedicated regions using Oracle Tuxedo Mainframe Modernization Runtimes UCM Image built for OCI deployment. This image incorporates Tuxedo core and all three mainframe runtimes – CICS, IMS, and Batch, as well as ART Test Manager and Tuxedo System and Application Monitor Plus for management and operations. This image is available with an elastic pricing model based on Universal Cloud Credits (UCC) or Bring-Your-Own-License (BYOL). You can deploy it on a variety of compute environments: bare metal, virtual machines, VMware cloud service, or Kubernetes-managed containers. Detailed architecture blueprints are available on OCI Reference Architecture center for Virtual Machine deployments and Kubernetes-managed containers.

   The database tier can continue to run on Exadata Cloud@Customer, which together with subscription-based elastic pricing for the application tier enables you to shift all CAPEX costs to OPEX, while retaining the security of the database in your own facilities protected by your own firewalls. The connections between the cloud-based application tier and locally-deployed Exadata Cloud@Customer can be secured through an IPSEC VPN or private peering provided through OCI FastConnect dedicated lines with lowest available latency.

4. **Fully Cloud.** Move from Hybrid option to Fully Cloud by using Exadata Cloud Service option in OCI. This couples the advantages of Exadata and Autonomous Database with the simplicity and elasticity of Oracle Cloud Infrastructure. Advanced cloud automation, dynamic resource scaling, and flexible subscription pricing enable you to run database workloads faster and at lower costs. Take advantage of storage autoscaling, OCI cross-AD and cross-region database replication for added resilience, or global scale database using Oracle Sharding.

Supporting Partial Migrations and Parallel Operations

For many large scale mainframe customers, the co-existence of re-hosted and mainframe environments is a long term requirement. In some cases, they re-host one or a few applications at a time, or some specific transactions and/or batch jobs that are responsible for peak MIPS. By lowering the peak, the overall cost of the mainframe environment can be significantly reduced.

For example, a major insurance company in Europe has been frequently exceeding its IBM high water mark of 4000 MIPS due to unpredictable load from the pricing transactions used in its quoting engine. Identifying and rapidly migrating these transactions to Tuxedo ART on three Linux servers enabled them to reduce peak loads by 1200 MIPS and get these peaks below the high water mark. Because these transactions communicated heavily with the rest of the CICS regions using Channels/Containers, robust CICS ISC support was essential. It was provided by Tuxedo Mainframe Adapter (TMA) and enabled migrated CICS transactions and those remaining on z/OS to interoperate at the rate of 100 transactions/second and exchange megabytes of data.

Oracle customers often run in such hybrid environments even before migration using a broad range of strong mainframe integration capabilities at an application and database level. To support such hybrid environments during multi-phase migration, or for ongoing parallel operations, customers leverage a comprehensive set of capabilities provided by Oracle Tuxedo, Tuxedo Mainframe Adapter, Oracle Database, Oracle GoldenGate, Oracle Database Gateways, along with DB2 Connect for IBM DB2, and Tuxedo MQ adapter for WebSphere MQ:

- Interoperability with CICS and IMS using Tuxedo Mainframe Adapters for TCP and SNA, supporting CICS DPL and TDQs over APPC, IMS OTMA, global transactions (Sync level 2/XA), security, and transaction routing for data consistency and integrity
- IBM MQ gateway in Oracle Tuxedo, supporting both MQ-triggered CICS transactions and MQ-IMS bridge
- Oracle/DB2 bi-directional data replication using Oracle GoldenGate
- IMS DB remote access using ODBA gateway in Tuxedo Application Runtime for IMS
- DB2 access via Oracle Database using Oracle Transparent Gateway (OTG) or directly from rehosted applications under Tuxedo using DB2 Connect with global transaction (XA/Sync Level 2) support across both Tuxedo and the mainframe application components
- RACF authentication for Tuxedo CICS and IMS users accessed using LDAP connection from Tuxedo via Tivoli Directory Server on z/OS and similar LDAP-proxied access to CA ACF2 or Top Secret.

In any kind of hybrid environment, security of the underlying connections between the cloud region and on-premises data center is paramount. Oracle Cloud Infrastructure provides multiple options for secure connections:

- **IPSec VPN:** VPN Connect provides site-to-site IPSec VPN connectivity between your on-premises network and VCNs in Oracle Cloud Infrastructure. The IPSec protocol suite encrypts IP traffic before the packets are transferred from the source to the destination and decrypts the traffic when it arrives.
- **Private peering:** OCI FastConnect provides an easy way to create a dedicated, private connection between your data center and Oracle Cloud Infrastructure. FastConnect provides higher-bandwidth options and a more reliable networking experience when compared with internet-based connections.

Managing Migration Project Risks

In addition to strong target platform and reference architecture, an industrialized methodology focused on risk mitigation is an essential ingredient in successful migration projects. Oracle and our partners have developed and honed a proven methodology for low risk migrations.

Oracle offers a comprehensive discovery process, where mainframe modernization experts delve into the details of the mainframe environment and applications, including the overall architecture, functional and technical dependencies, integration requirements, and performance and availability SLAs. The discovery also covers target architecture requirements, production deployment architecture, development and test requirements, and enterprise standards for High Availability and Disaster Recovery. This comprehensive discovery process results in a report that

documents the findings, maps source environment to target architecture and software components (not only IBM software, but many 3rd party mainframe products), and provides specific migration recommendations and roadmap to guide the project.

Following the initial analysis, additional focus areas must be studied and documented, resulting in a series of deliverables, including:

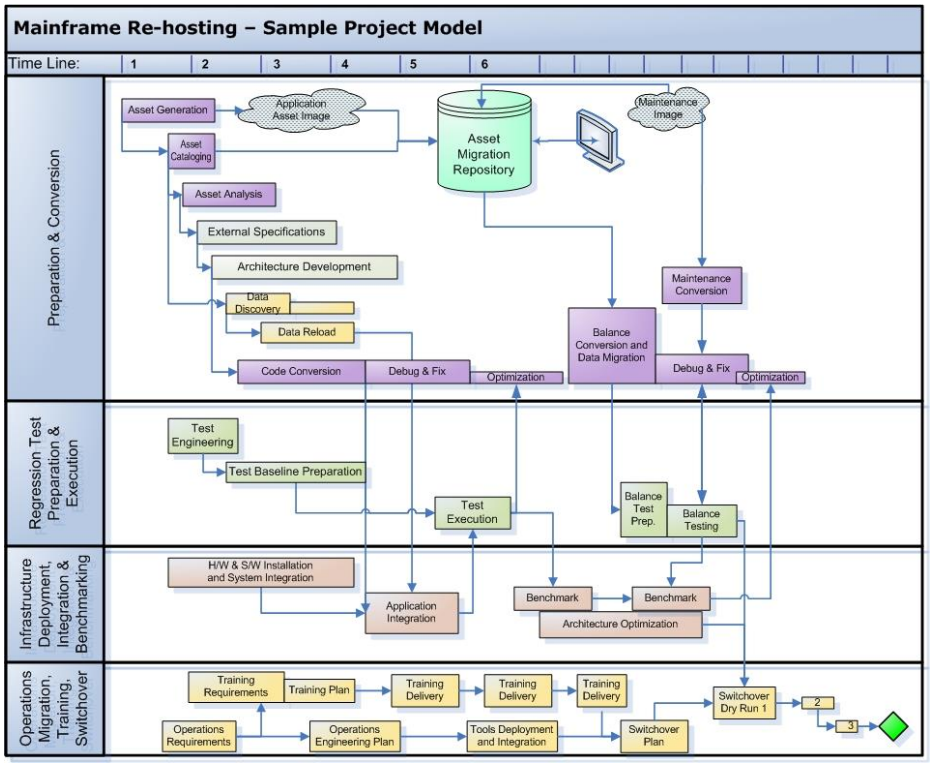
- Migration plan with clear scope definition, project roles and responsibilities, timeline, dependencies, and budget
- An externals specification that identifies integration requirements and replacement software packages and specifies how the integration interfaces and replacement software will be provided on target
- Deployment architecture blueprint that defines production configurations, dev/test environments, and DR systems, as well as integrations into the IT operations, monitoring, and management ecosystem
- Testing plan that defines types of testing to be performed (e.g., regression, integration, performance, stability/resilience, etc.), tools required, and test scenarios and artifacts required to execute and evaluate them
- Training plan based on mapping existing skill sets to those required in the new environment and recommended training for developers, system administrators, production operations, etc.
- Switch-over plan that defines approach to moving users from mainframe to re-hosted application, including production data synchronization, and fail-back procedures in case of unforeseen issues

To support these, an assessment at the code and data level may be performed to determine the level of complexity, 3rd party/packaged software dependencies, data access patterns, and identify any areas that need additional analysis and specification. This is often done jointly with Oracle partners who specialize in mainframe migrations and have been trained on Oracle solution and methodologies.

The assessment is also used to identify a subset of the application for potential pilot migration. The role of a migration pilot is three-fold:

- Migrate a part of the application and data to validate the automated approach and evaluate any specific technical concerns
- Deploy and benchmark the migrated portion on the target architecture to validate the performance and other SLAs, and apply the results to capacity planning
- Validate the testing approach and verify that customer's test libraries provide sufficient coverage or need to be supplemented through automated capture of test cases from the production environment

Figure 6. Comprehensive Mainframe Migration Planning and Project Execution Framework



A pilot project provides a wealth of information that can be used to adjust the project plans and other deliverables mentioned above based on the actual application environment, and thus increase the confidence in the overall plan and speed up the rest of the migration project.

Once the decision is made to go forward beyond the pilot, multiple project tracks can be used to parallelize the effort and speed up the project timeline. Typically at least four tracks running in parallel are recommended to optimize the project duration:

- Core migration of code and data
- Testing preparation and execution
- Infrastructure deployment and integration
- Training and operations migration

While the project moves forward, the normal application maintenance and evolution continues, and this must be taken into account in project planning. An important benefit of Oracle's automated approach is that all conversion work is 100% automated – any changes in the migration rules or custom extensions are captured and incorporated in the Workbench. This makes it possible to re-run the entire conversion process at any time.

Based on incremental processing capabilities of the Workbench tools and automated re-processing that produces consistent results, the maintenance changes can be brought into the project towards the end and easily processed using the complete rule set. This enables "frozen" windows to be minimized since the freeze is only necessary at the very end when the maintenance changes are incorporated and final stages of regression testing are executed.

The Bottom Line

Your partnership with Oracle presents a unique opportunity for you to get more value from your legacy applications, while greatly reducing their infrastructure cost. With Oracle's mainframe re-hosting solution you get a unified, flexible technology platform that combines the mainframe-class RASP with advanced rehosting capabilities, supported by Oracle training, support, and consulting services and a broad ecosystem of delivery partners. Freed from the mainframe lock-in, your application assets can help you to get the most from your business.

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