Oracle Database 12c Best Practices for Data Availability and Disaster Protection

Joseph Meeks, Oracle
Lawrence To, Oracle
Chris Chesney, Thomson Reuters
The following is intended to outline our general product direction. It is intended for information purposes only, and may not be incorporated into any contract. It is not a commitment to deliver any material, code, or functionality, and should not be relied upon in making purchasing decisions. The development, release, and timing of any features or functionality described for Oracle’s products remains at the sole discretion of Oracle.
Program Agenda

- Oracle Database High Availability and Data Protection
- Bronze Service
- Silver Service
- Gold Service
- Thomson Reuters
Oracle Maximum Availability Architecture

Production Site
- RAC
  - Scalability
  - Server HA
- Flashback
  - Human error correction

Active Replica
- Active Data Guard
  - Data Protection, DR
  - Query Offload
- GoldenGate
  - Active-active
  - Heterogeneous

Enterprise Manager Cloud Control
- Coordinated Site Failover
Application Continuity
- Application HA
Global Data Services
- Service Failover / Load Balancing

Edition-based Redefinition, Online Redefinition, Data Guard, GoldenGate
- Minimal downtime maintenance, upgrades, migrations

RMAN, Oracle Secure Backup
- Backup to disk, tape or cloud

Coordinated Site Failover
Application Continuity
Service Failover / Load Balancing
Where do you start?
Establish Service Level Objectives
High Availability (HA) and Data Protection

- Standardize: Three proven HA architectures
- Consolidate: Reduce capital and operational costs
- Simplify: Reduce risk
Oracle Database 12c
Not Your Grandfather’s Maximum Availability Architecture

- Best database consolidation
- Zero data loss at any distance
- Real transparent application failover
Oracle Database 12c MAA
Best Practice Service Level Tiers for Database as a Service

GOLD
Zero application outage
Zero data loss

SILVER
Seconds to minutes of downtime
Near-zero or zero data loss

BRONZE
Minutes to days of downtime
Data protected as of last backup
Quick Definition of Terms

- **RTO**
  - Recovery Time Objective
  - Maximum length of time an application is not available
- **RPO**
  - Recovery Point Objective
  - Maximum amount of data (measured in time) that can be lost
BRONZE
Bronze Service – Single Instance MAA
RTO of Minutes to Days, RPO From Last Backup

- Reduce cost of HA and data protection
  - HA features built-in for single instance
  - Restore from backup
- Reduce cost through consolidation
  - Oracle Multitenant
  - Resource Management
- Simplify (Eng Systems)
<table>
<thead>
<tr>
<th>Automatic Storage Management</th>
<th>Flashback Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drop, Query, Transaction, Table, and Database</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Online Redefinition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Online Reorganization</td>
</tr>
<tr>
<td>Edition Based Redefinition</td>
</tr>
<tr>
<td>Online File Move</td>
</tr>
<tr>
<td>Online Patching</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bronze Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Instance MAA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Oracle Restart</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recovery Manager (RMAN)</td>
</tr>
<tr>
<td>Fast Recovery Area</td>
</tr>
<tr>
<td>Oracle Secure Backup</td>
</tr>
</tbody>
</table>
## Oracle Data Protection

### Bronze - Single Instance MAA

<table>
<thead>
<tr>
<th>Capability</th>
<th>Physical Block Corruption</th>
<th>Logical Block Corruption</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Manual checks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dbverify, Analyze</td>
<td>Physical block checks</td>
<td>Logical checks for intra-block and inter-object consistency</td>
</tr>
<tr>
<td>RMAN</td>
<td>Physical block checks during backup and restore</td>
<td>Intra-block logical checks</td>
</tr>
<tr>
<td><strong>Runtime checks</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Database</td>
<td>In-memory block and redo checksum</td>
<td>In-memory intra-block checks</td>
</tr>
<tr>
<td>ASM</td>
<td>Automatic corruption detection and repair using extent pairs</td>
<td></td>
</tr>
<tr>
<td>Exadata</td>
<td>HARD checks on write</td>
<td>HARD checks on write</td>
</tr>
</tbody>
</table>
Multitenant and Oracle MAA
High Availability and Data Protection for Consolidate Environments

- **Oracle Multitenant**
  - Highest consolidation density
  - Simplest management – Manage as One

- **Oracle MAA**
  - HA and data protection optimized for Oracle
ZFS Backup Appliance

General Purpose Backup Solution

- Feature-rich
  - Thin provisioning
  - Snapshot and Cloning
  - Replication
- Good performance
  - Benchmarked with Exadata
    - 20TB/h backup rate
    - 9.4TB/h restore rate

# Unplanned Outages and Planned Maintenance

## Bronze - Single Instance MAA

<table>
<thead>
<tr>
<th>Events</th>
<th>Downtime</th>
<th>Data Loss Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unplanned Outages</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instance failure</td>
<td>Minutes</td>
<td>Zero</td>
</tr>
<tr>
<td>Node failure, data corruptions, database failures or site failures</td>
<td>Hours to days</td>
<td>Since last backup</td>
</tr>
<tr>
<td><strong>Planned Maintenance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Online File Move, Online Reorganization and Redefinition,</td>
<td>Zero to near-zero</td>
<td>Zero</td>
</tr>
<tr>
<td>Online Patching, App upgrade with Editions Based Redefinition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating System or Database upgrades</td>
<td>Minutes to hours</td>
<td>Zero</td>
</tr>
<tr>
<td>Platform migrations or application upgrades</td>
<td>Hours to day</td>
<td>Zero</td>
</tr>
</tbody>
</table>
Bronze Evolution: Near Zero RPO, a Preview
Oracle Database Backup Logging Recovery Appliance

Database Backup Logging
Recovery Appliance

1000s of
Client Databases

Optional
Archive to Tape

www.oracle.com/databasebackupappliance
# Unplanned Outages and Planned Maintenance

## Bronze - Single Instance MAA Future (Future)

<table>
<thead>
<tr>
<th>Events</th>
<th>Downtime</th>
<th>Data Loss Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unplanned Outages</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instance failure</td>
<td>Minutes</td>
<td>Zero</td>
</tr>
<tr>
<td>Node failure, data corruptions, database failures or site failures</td>
<td>Hours to days</td>
<td>Near Zero (vs since last backup)</td>
</tr>
<tr>
<td><strong>Planned Maintenance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Online File Move, Online Reorganization and Redefinition, Online Patching, App upgrade with Editions Based Redefinition</td>
<td>Zero to near-zero</td>
<td>Zero</td>
</tr>
<tr>
<td>Operating System or Database upgrades</td>
<td>Minutes to hours</td>
<td>Zero</td>
</tr>
<tr>
<td>Platform migrations or application upgrades</td>
<td>Hours to day</td>
<td>Zero</td>
</tr>
</tbody>
</table>
SILVER
Silver Service: Real-Time Recovery
RTO of Seconds to Minutes, RPO of Zero or Near-Zero

Bronze plus:
- Server and instance HA
  - RAC One Node
- Database and site HA
  - Active Data Guard
    - Best corruption protection
    - Rolling maintenance
Instance and Node Failover

Oracle RAC One Node Provides Cold-Failover Functionality

- On failure of
  - a database (DB) instance
  - Or the server hosting the DB
  - Or other failures impacting operation

- Oracle RAC One Node will fail over the database instance to another server in the cluster

- Online Database Relocation also minimizes downtime during many types of scheduled maintenance operations.
Data Guard Does What Storage Mirroring Can’t
Isolate Corruption, Protect Data, Maintain Availability

“(storage uses) a remote mirroring model…any potential data corruption would be copied faithfully and expeditiously to the other side”

VP Global Marketing of a Leading Storage Company
Data Guard Replication
Fundamentally Different From Storage Mirroring

Storage Remote Mirroring… blocks are just bits on a disk

Application-aware physical and logical data consistency checks guarantee end to end data integrity

Checksum is the only validation method

Far superior than storage level checksum
My Oracle Support Note 1302539.1
Active Data Guard Architecture
Oracle Aware Process Maintains an Exact Physical Copy of Production

Primary Database
Oracle Instance (in memory)
Oracle data files
Recovery files

Active Standby Database
Open Read-Only
Oracle Instance (in memory)
Oracle data files
Recovery files
Redo Apply

SYNC or ASYNC
database redo
Storage Remote Mirroring Architecture
Generic - Must Mirror Every Write to Every File

Primary Database
- Oracle Instance (in memory)
  - Recovery files
  - Oracle data files

SYNC or ASYNC block replication

Remote Volumes
- Zero Oracle validation
- 7x network volume
- 27x network i/o
- Zero production offload, no access to db files

Oracle data files

Recovery files

Recovery files

Oracle data files
Corruption and Production Offload Demos

- PEOPLESOFT Active Data Guard demo
- Auto repair of data block corruptions with Active Data Guard
<table>
<thead>
<tr>
<th>Capability</th>
<th>Physical Block Corruption</th>
<th>Logical Block Corruption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual checks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dbverify, Analyze</td>
<td>Physical block checks</td>
<td>Logical intra-block and inter-object consistency</td>
</tr>
<tr>
<td>RMAN</td>
<td>Physical block checks during backup and restore</td>
<td>Intra-block logical checks</td>
</tr>
<tr>
<td>Active Data Guard</td>
<td>• Continuous physical block checking at standby</td>
<td>• Detect lost write corruption, auto shutdown and failover</td>
</tr>
<tr>
<td></td>
<td>• Strong isolation eliminates single point of failure</td>
<td>• Intra-block logical checks at standby</td>
</tr>
<tr>
<td></td>
<td>• Automatic repair of physical corruptions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Automatic failover</td>
<td></td>
</tr>
<tr>
<td>Runtime checks</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Database</td>
<td>In-memory block and redo checksum</td>
<td>In-memory intra-block checks</td>
</tr>
<tr>
<td>ASM</td>
<td>Automatic corruption detection and repair using extent pairs</td>
<td></td>
</tr>
<tr>
<td>Exadata</td>
<td>HARD checks on write</td>
<td>HARD checks on write</td>
</tr>
</tbody>
</table>
# Unplanned Outages and Planned Maintenance

## Silver – Real Time Recovery

<table>
<thead>
<tr>
<th>Events</th>
<th>Downtime</th>
<th>Data Loss Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unplanned Outages</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instance failures</td>
<td>Seconds (vs minutes)</td>
<td>Zero</td>
</tr>
<tr>
<td>Node failures, Data corruption, database failure or site failure</td>
<td>Seconds to minutes (vs hours to days)</td>
<td>Near Zero (vs since last backup)</td>
</tr>
<tr>
<td><strong>Planned Maintenance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Online File Move, Online Reorganization and Redefinition, Online Patching, App upgrade with Editions Based Redefinition</td>
<td>Zero to near-zero</td>
<td>Zero</td>
</tr>
<tr>
<td>Operating System or Database upgrades</td>
<td>Seconds to minutes (vs minutes to hours)</td>
<td>Zero</td>
</tr>
<tr>
<td>Some Platform migrations</td>
<td>Seconds to minutes (vs hours to day)</td>
<td>Zero</td>
</tr>
<tr>
<td>Cross endian platform migrations, Application upgrades</td>
<td>Hours to Days</td>
<td>Zero</td>
</tr>
</tbody>
</table>
Gold Service: Application Continuity
Zero Application Outage, Zero Data Loss

Silver plus:
- Scalability and HA
  - Oracle RAC
- Zero application outage
  - Application Continuity
- Zero data loss over WAN
  - Active Data Guard Far Sync
- Zero downtime maintenance
  - Oracle GoldenGate
  - Bi-directional replication
Application Continuity
Masks Unplanned/Planned Outages

- Replays in-flight work on recoverable errors
- Masks many hardware, software, network, storage errors and outages when successful
- Improves end-user experience and productivity without requiring custom app development
Application Continuity Requires Zero Data Loss
Not Possible in Typical WAN Deployment in Oracle 11g
Active Data Guard Far Sync
Zero Data Loss Protection and Application Continuity at ANY Distance

Primary: New York
Standby: London
Far Sync: Zero data loss failover

Data Guard ASYNC (compressed)
Application Continuity Demonstrations

- Application Continuity Demo with RAC
- Application Continuity Demo with ADG

Demos will be published on www.oracle.com/goto/maa
Application Continuity

Example Java App Using Universal Connection Pool (UCP)
Application Continuity
Using Service Configured for FAN / Replay and Replay Driver

Number of DB Sessions (threads) = 100
Transactions per thread = 50
Think time (ms) = 20

Service = apcon_hop_ac3
Username = ucptest
*** Using Replay Driver ***

During execution, Press Q to Quit or T for timestamp.
Press Enter to begin

Obtaining connections...

Timestamp: 17:10:07, Active Sessions: 100, TPS: 654, Avg. Response Time (ms): 128.1,
Application Continuity

Using Service for FAN and NON-Replay Driver

Number of DB Sessions (threads) = 100
Transactions per thread = 50
Think time (ms) = 20

Service = oltp_fan
Username = ucptest
*** NOT Using Replay Driver ***

During execution, Press Q to Quit or T for timestamp.
Press Enter to begin

Obtaining connections...

Timestamp: 17:10:13, Active Sessions: 100, TPS: 3,376, Avg.
Timestamp: 17:10:15, Active Sessions: 100, TPS: 3,336, Avg.
Application Continuity

Seamless failover of application connections with RAC

No Interruption

 Interruption
Application Continuity

Seamless failover of application connections with RAC

- **App Using Application Continuity:**

  - TPS: 3,392, Avg. Response Time (ms): 4.4, Expected TXN count: 5,000, Actual TXN count: 5,000, Error count: 0
  - TPS: 3,422, Avg. Response Time (ms): 4.5, Expected TXN count: 5,000, Actual TXN count: 5,000, Error count: 0
  - TPS: 581, Avg. Response Time (ms): 103.7, Expected TXN count: 5,000, Actual TXN count: 5,000, Error count: 0
  - TPS: 3,365, Avg. Response Time (ms): 4.7, Expected TXN count: 5,000, Actual TXN count: 5,000, Error count: 0
  - TPS: 1,117, Avg. Response Time (ms): 64.4, Expected TXN count: 5,000, Actual TXN count: 5,000, Error count: 0
  - TPS: 3,394, Avg. Response Time (ms): 4.8, Expected TXN count: 5,000, Actual TXN count: 5,000, Error count: 0
  - TPS: 3,344, Avg. Response Time (ms): 5.3, Expected TXN count: 5,000, Actual TXN count: 5,000, Error count: 0

- **App NOT Using Application Continuity:**

```
java.sql.SQLRecoverableException: No more data to read from socket
        The connection is closed
        Connection Time (ms): 74.3, Expected TXN count: 5,000, Actual TXN count: 4,950.
        Error count: 50
```
Application Continuity
Seamless failover of application connections with Active Data Guard

Oracle Database 12c Enterprise Edition Release 12.1.0.1.0 - 64bit Production
With the Partitioning, Real Application Clusters, Automatic Storage Management,
OLAP,
Advanced Analytics and Real Application Testing options

SQL> select database_role from v$database;

<table>
<thead>
<tr>
<th>DATABASE_ROLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRIMARY</td>
</tr>
</tbody>
</table>

SQL> shutdown abort;
ORACLE instance shut down.

Initiating reinstatement for database "apcona"...
Reinstating database "apcona", please wait...

Reinstatement of database "apcona" succeeded
19:36:39.95 Sunday, September 22, 2013
Observer started

09:32:15.52 Monday, September 23, 2013
Initiating Fast-Start Failover to database "apcona"...
Performing failover NOW, please wait...
Failover succeeded, new primary is "apcona"
09:32:44.53 Monday, September 23, 2013
# Application Continuity

Seamless failover of application connections with Active Data Guard

<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>09:32:03</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>09:32:04</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>09:32:04</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>09:32:05</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>09:32:06</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>09:32:07</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>09:32:07</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>09:32:08</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>09:32:09</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>09:32:09</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>09:32:10</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>09:32:10</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>09:32:11</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>09:32:11</td>
<td>-------------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>

Momentary increase in response time - but no errors are thrown because of Application Continuity (AC) in conjunction with Data Guard Fast_Start Failover.
Oracle GoldenGate
Zero Application Downtime for Upgrades, Migrations, Active/Active HA

- Active-Active deployment considerations:
  - Pre-requisites for logical replication, conflict detection and resolution
  - Replication performance can vary by workload
  - Asynchronous, each copy requires a Data Guard standby for zero data loss
Example: Zero Downtime Upgrades & Migrations

START: Production Running on Current Version

Primary Database (version n)

ACTIVE DATA GUARD SYNC/ASYNC

Active Data Guard Standby Database (version n)
Phase 1
Create Clone, Upgrade, then Synchronize Using GoldenGate

Primary Database (version n) → ACTIVE DATA GUARD SYNC/ASYNC → GoldenGate Uni-Directional → Active Data Guard Standby (version n)

Create clone, upgrade, and synchronize (version n+1)
Phase 2
Create Standby at New Version, Gradually Migrate Users to New Primary

Primary Database (version n)

Active Data Guard Standby (version n+1)

GoldenGate Bi-Directional

Active Data Guard Standby (version n)

New Primary Database (version n+1)
Finish
Retire Prior Version and Redeploy Assets when Migration is Complete
# Unplanned Outages and Planned Maintenance

## Gold - Mask Outages to Users and Applications

<table>
<thead>
<tr>
<th>Events</th>
<th>Downtime</th>
<th>Data Loss Potential</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unplanned Outages</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Instance or Node failures</td>
<td>Zero application outage</td>
<td>Zero</td>
</tr>
<tr>
<td>Data corruptions, database failures or site failures</td>
<td>Zero application outage</td>
<td>Zero</td>
</tr>
<tr>
<td><strong>Planned Maintenance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Online File Move, Online Reorganization and Redefinition, Online Patching, App upgrade with Edition Based Redefinition</td>
<td>Zero application outage</td>
<td>Zero</td>
</tr>
<tr>
<td>Operating System or Database upgrades</td>
<td>Zero application outage</td>
<td>Zero</td>
</tr>
<tr>
<td>• Platform migrations or application upgrades</td>
<td>Zero to near-zero</td>
<td>Zero</td>
</tr>
<tr>
<td>• Unplug/plug migration between HA service levels</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Summary

<table>
<thead>
<tr>
<th>Architecture</th>
<th>BRONZE</th>
<th>SILVER</th>
<th>GOLD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Instance MAA</td>
<td>RMAN backups</td>
<td>MAA with Real-Time Failover</td>
<td>All MAA Capabilities</td>
</tr>
<tr>
<td></td>
<td></td>
<td>RAC One, Active Data Guard</td>
<td></td>
</tr>
<tr>
<td>RTO Target</td>
<td>Minutes to days</td>
<td>Seconds to minutes</td>
<td>Zero application outage</td>
</tr>
<tr>
<td>RPO Target</td>
<td>Since last backup</td>
<td>Near-zero or zero</td>
<td>Zero</td>
</tr>
<tr>
<td>Key Benefits</td>
<td>• Minimize CapEx</td>
<td>• No single point of failure</td>
<td>• Zero application outage</td>
</tr>
<tr>
<td></td>
<td>• Minimize OpEx</td>
<td>• Complete data protection</td>
<td>• Zero downtime for planned</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Fast failover</td>
<td>maintenance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Minimal planned downtime</td>
<td>• Scalable performance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Offload read-only workload</td>
<td></td>
</tr>
</tbody>
</table>
ORACLE MAXIMUM AVAILABILITY ARCHITECTURE

Chris Chesney, Senior Director, Database & Middleware
THOMSON REUTERS DATABASE SCALE

• Oracle Database Environment
  – Over 1200 Databases Deployed
  – Over 2400 Instances Deployed
  – Over 1 PB Of Allocated Storage
  – Over 350 New Instances Deployed Last Year
1. BUILDING BLOCKS

• TR Building Blocks
  – Linux, Intel, Oracle, NAS

• MAA Best Practices
  – Oracle RAC
  – Active Data Guard
  – Oracle GoldenGate
2. STANDARD DEPLOYMENT PATTERNS

- **Content Publishing**
- **Content Delivery**
- **User Data**

Diagram showing the flow from Data Feeds to Editorial Staff, then to Content Delivery, and finally to Customers.
CONTENT PUBLISHING

• Content Systems
  – Acquire/Enhance Content
  – Publish to Content Delivery Systems
  – Minutes of Downtime Tolerable

• Protection from
  – Hardware Failures
  – Site Failure
  • Active Data Guard Role Switch
CONTENT DELIVERY

• Online Systems
  – 7x24x365
  – Zero Downtime for Read

• Protection from
  – Hardware Failures
  – Site Failure (Publishing Downtime)
USER DATA

• Customer Facing Products
  – Enhanced User Experience
  – Device Independence
  – Software as a Service (SaaS)
  – Zero Downtime for Read/Write

• Protection from
  – Hardware Failures
  – Site Failure
SERVICE LEVEL TIERS

**GOLD**
- Zero read-write outage
- Near-zero data loss

**SILVER**
- Zero read outage
- Near-zero data loss

**BRONZE**
- Minutes of downtime
- Near-zero data loss
3. BUILDING SYSTEMS

- Patterns combined to build systems
BRINGING IT ALL TOGETHER

MAA Resources

- [www.oracle.com/goto/maa](http://www.oracle.com/goto/maa)