JBoss Middleware for Spacecraft Trajectory Operations

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Abstract

- Project Background
  - What is the environment where we are considering Open Source Middleware?
- System Architecture
  - What technologies and design did we apply?
- Testing overview
  - What are the quality scenarios and test points?
- Project Conclusion
  - What did we learn about Open Source Middleware?

Project Background

- What is our core business?
- What is our software environment?
- What is our software need?
- What are our project goals?

Core Business

- We perform all of the Trajectory Analysis, Pre-mission Design, Operations, and Post-Flight Assessments for the Manned Space Program
  - We support the Space Shuttle Program (SSP), International Space Station (ISS), Constellation Program (CxP) and other vehicles
  - We support Ascent, Orbit, Rendezvous, and Entry Phases

Core Business

- Analysis:
  - How changes in the vehicle, environment, or procedures impact the vehicles trajectory, performance, and margins.
  - Both nominal and off-nominal conditions.
  - We answer “what if” type questions
- Pre-Mission Design:
  - Determines what the specific trajectory will be for an upcoming launch or mission phase
  - Determines the margins for the flight
  - Results in products that are consumed by the rest of the program

Core Business

- Operations:
  - Monitor the vehicle, Determine where the vehicle is, Tell the vehicle how to get where it needs to go
  - During critical phases (Ascent, Rendezvous, and Entry) system failures cannot be tolerated and performance is a key concern
    - Possible loss of crew and loss of vehicle
  - Done by flight controllers in a highly collaborative environment. A lot of concurrent use of data and user interaction with the system.

- Software environment

  - Mission Critical Flight Control Operations
  - Software systems with legacies dating 40 years.
  - Highly Customized infrastructure
  - New space program requiring considerable new functional capabilities

- Software Need

  - Highly available computing system
  - Sustainable infrastructure and applications
  - Modifiable infrastructure, applications, and business models

Project Background

- Project Goals

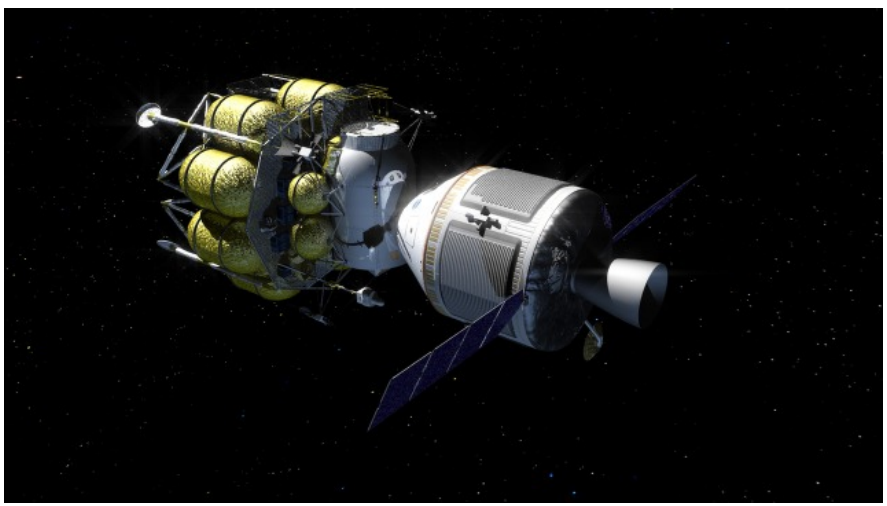
  - Determine if Java technology is appropriate for high availability.

  - Determine if Java Open Source Middleware is a viable alternative to custom infrastructure.

  - Determine if JBoss Enterprise Application Platform can support our use cases and quality scenarios.

System Architecture

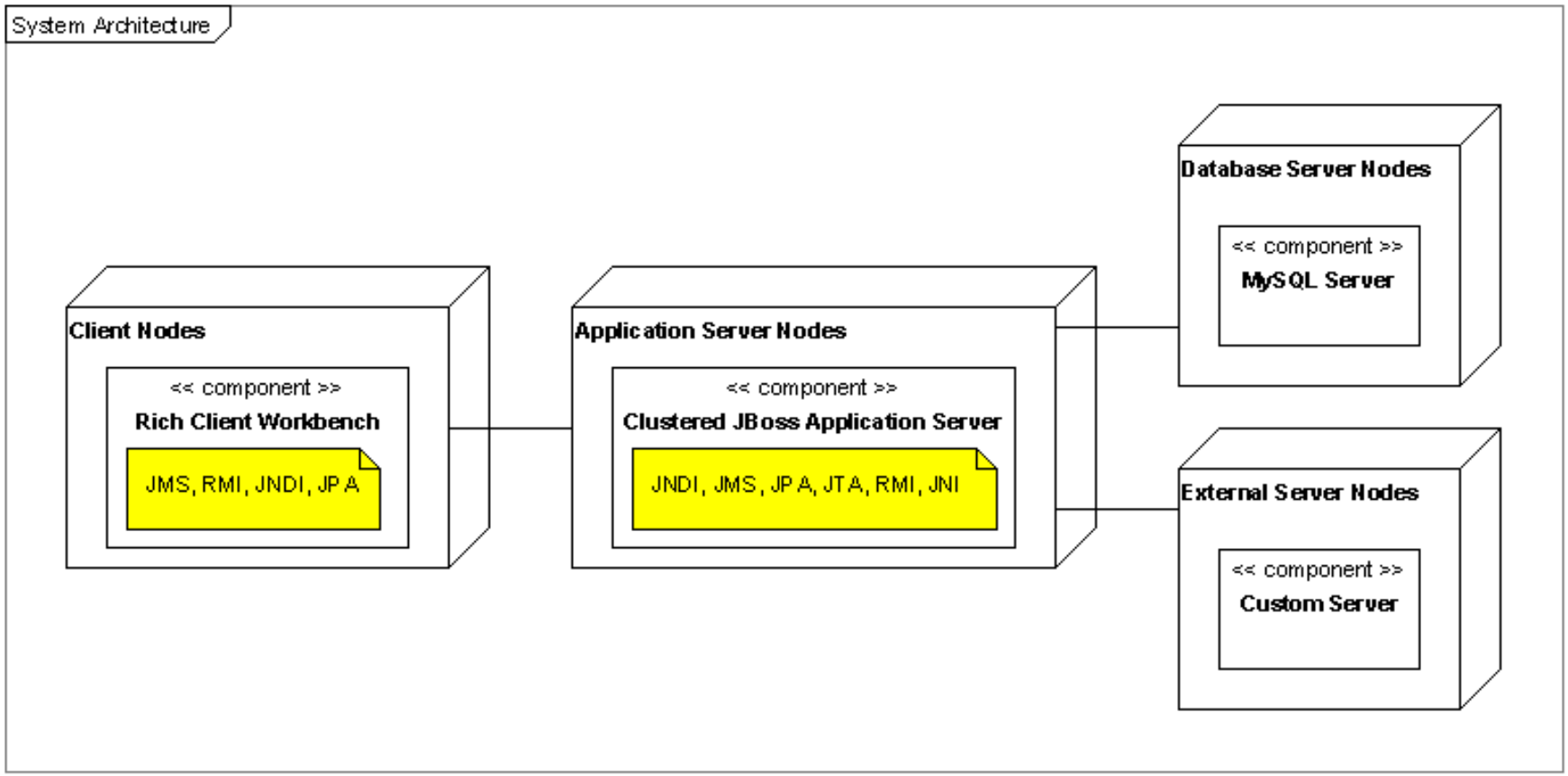
- What are the technologies employed?
- What is the test system architecture?
- What is the test application design?



System Architecture

- Technologies
  - Blade Server
  - RHEL
  - Sun JVM
  - MySQL (clustered for failover and redundancy)
  - JBoss AS (EJB3 and Service Beans)
  - JBoss Clustering (failover and redundancy)
  - JBoss Messaging (data distribution)
  - JBoss Cache (object state replication)
  - JGroups (failover of services)
  - Hibernate (object persistence)

System Architecture



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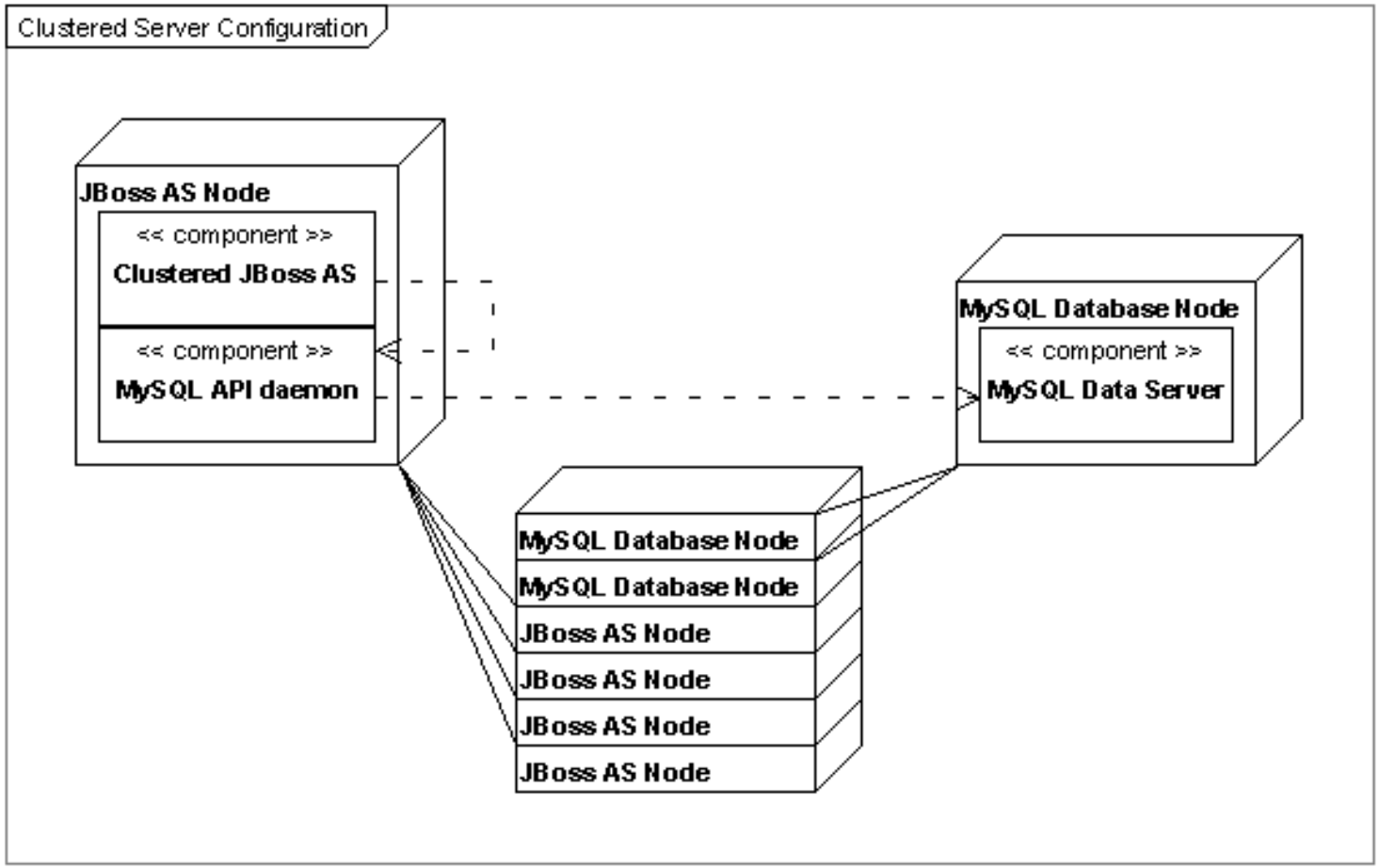

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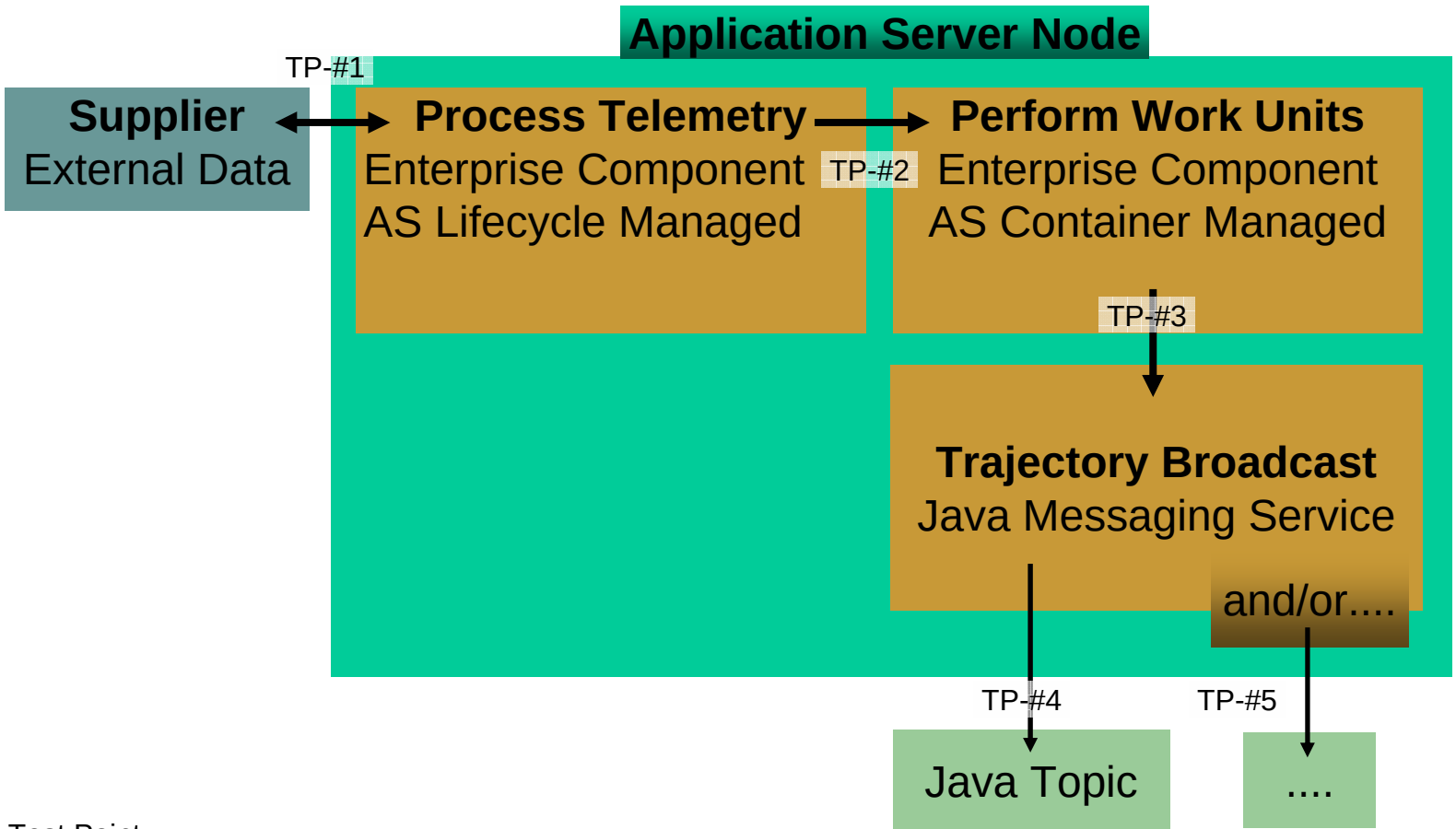
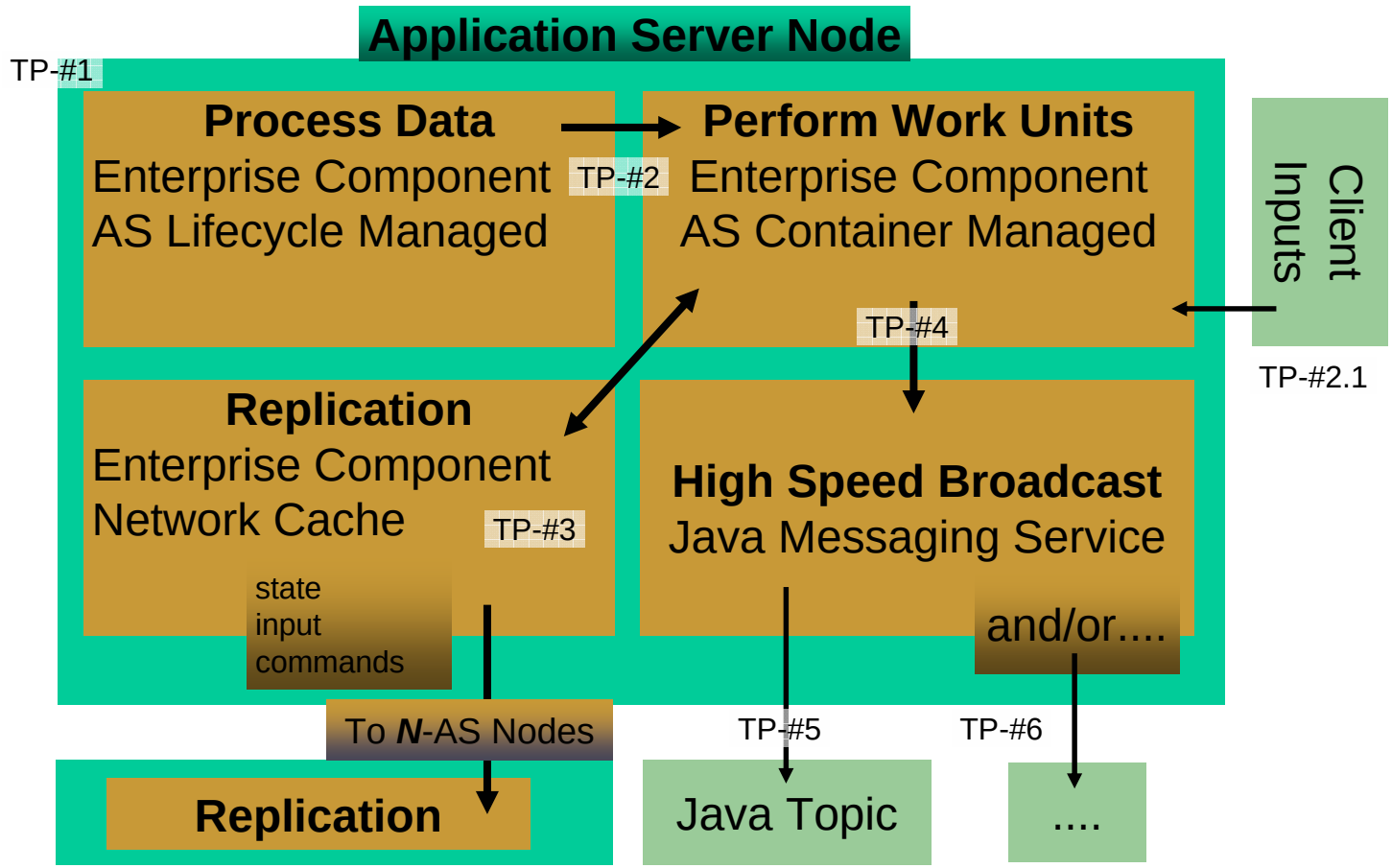


TP - Test Point

System Architecture



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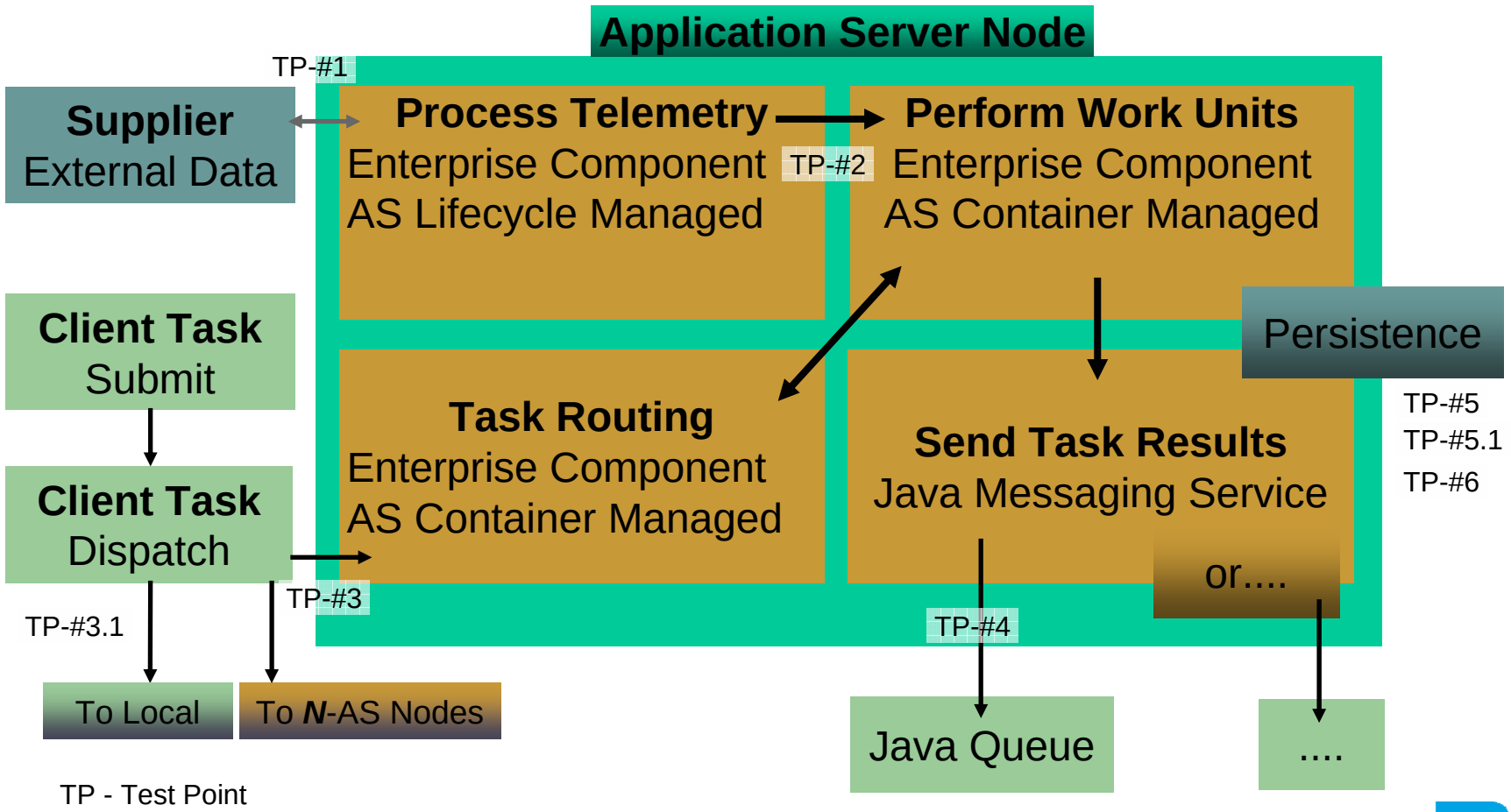

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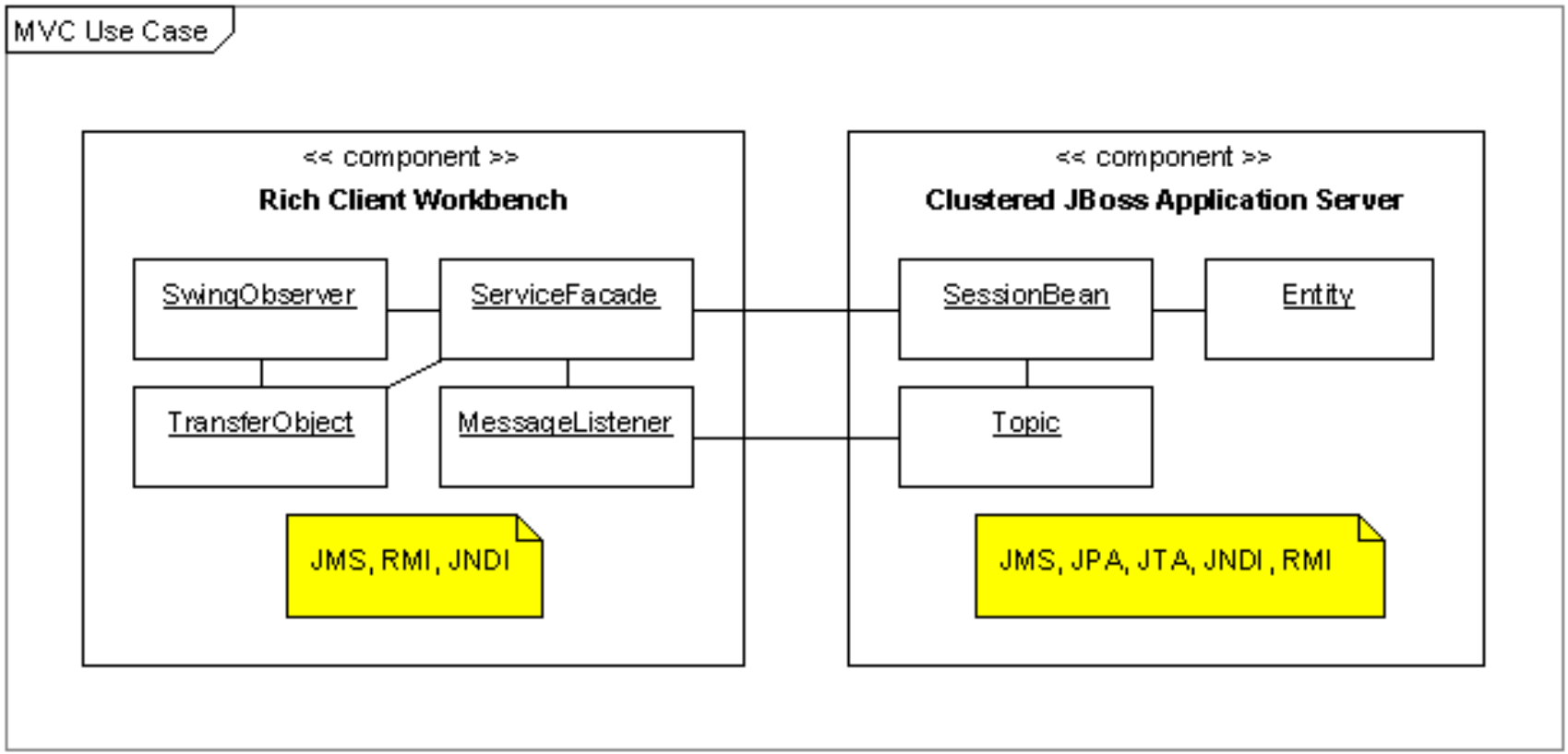

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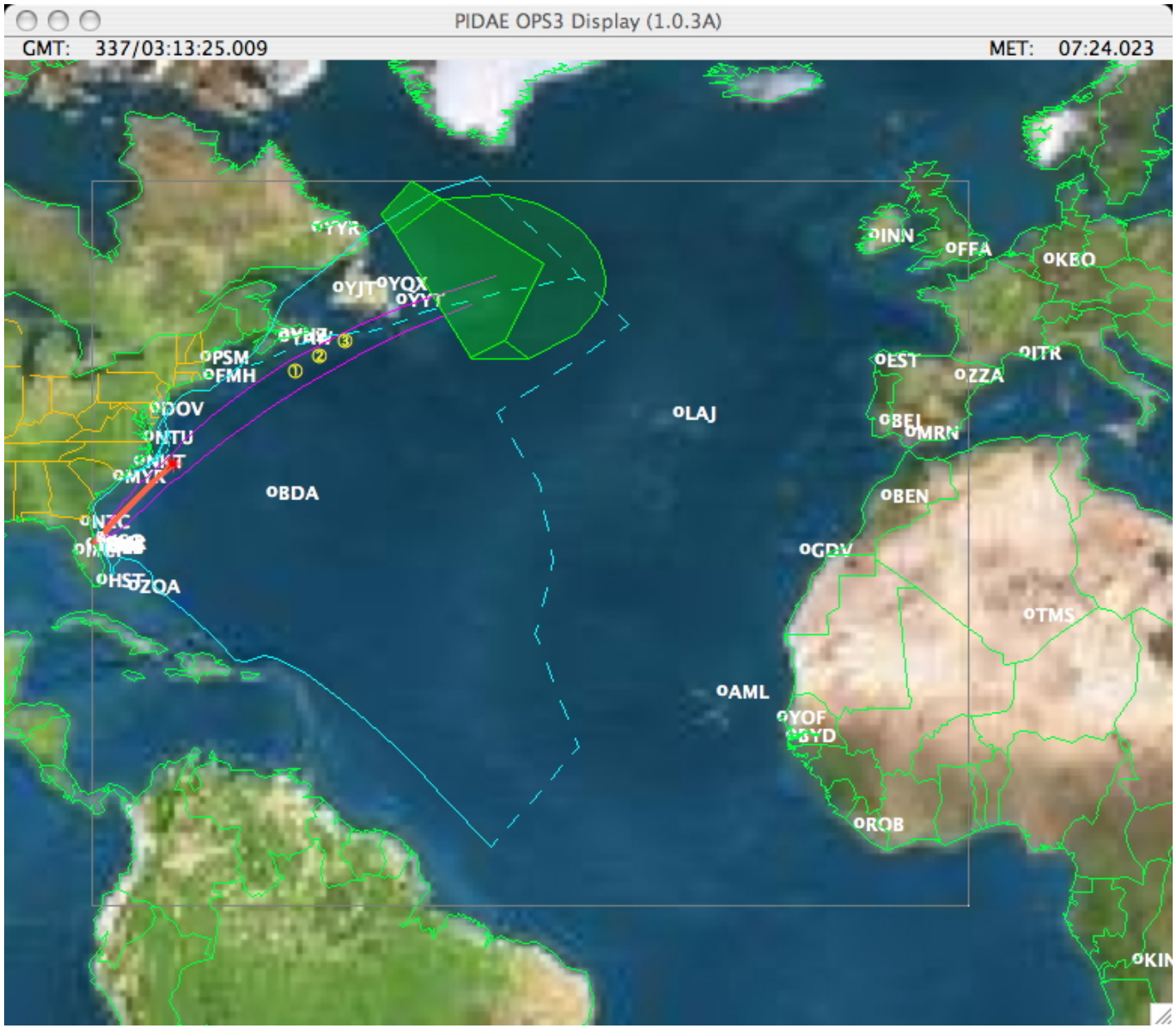

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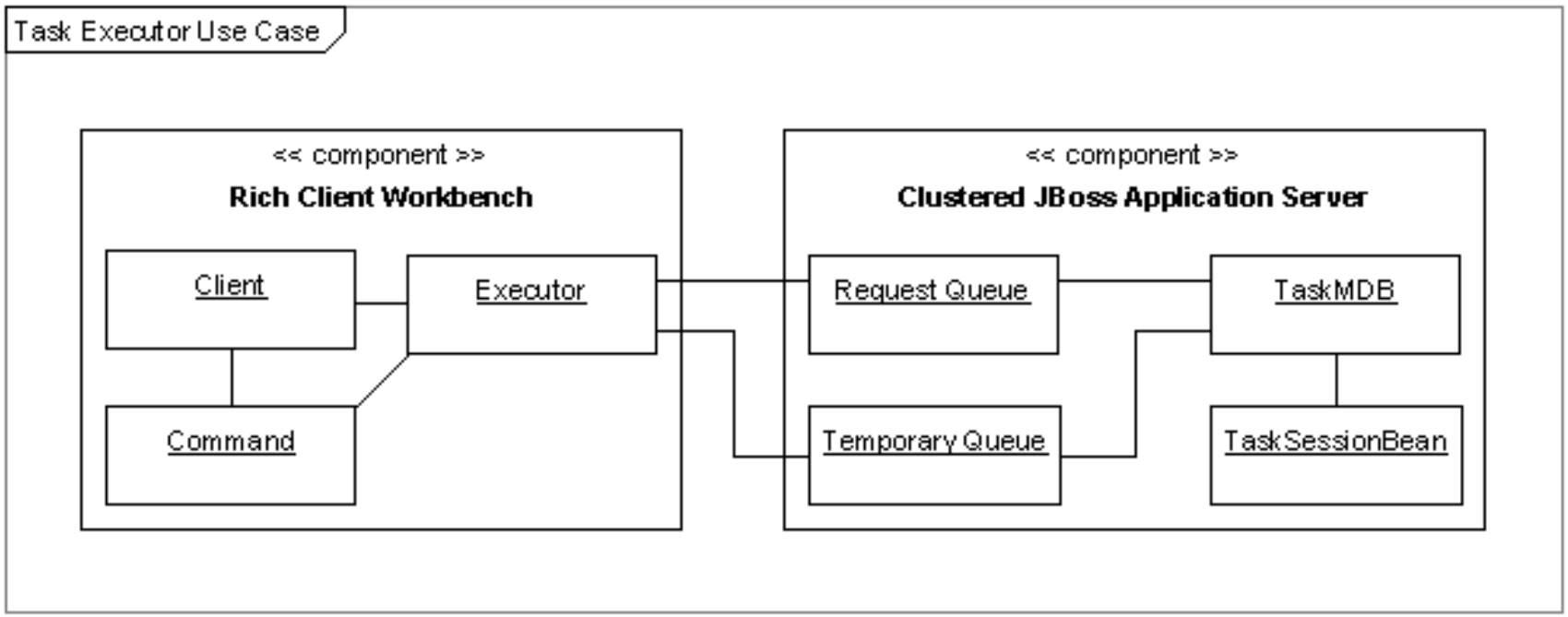

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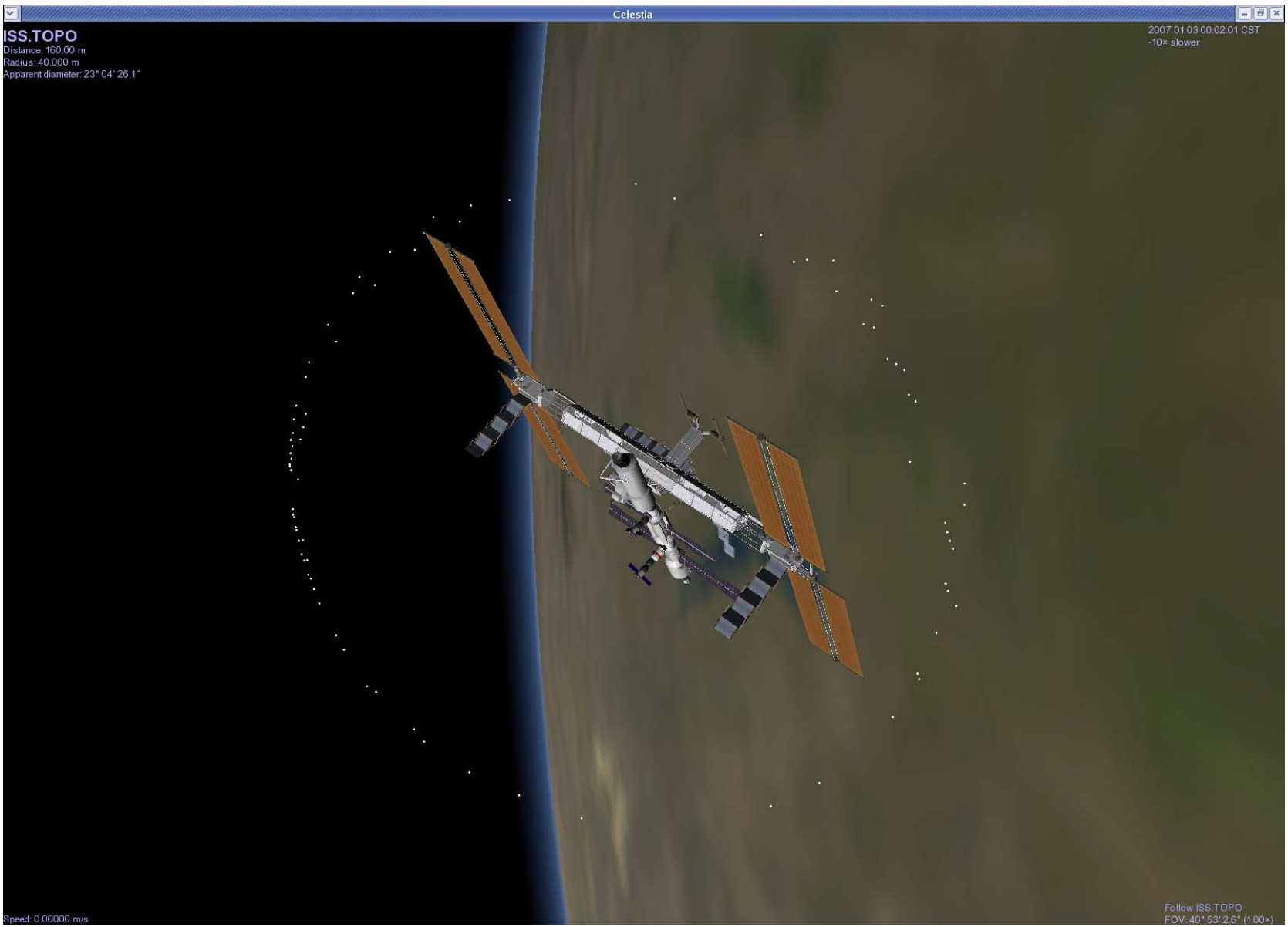

Testing Overview

- What are the primary quality attributes and measures?
- What are our test criteria?
- What technologies were tested?
- What are our test results?

Primary Attributes & Measures

- Reliability
  - failover and fault recovery time in seconds of both processing load and connections

- Performance
  - processing load in compute units
  - data latency in seconds
  - data distribution in megabytes per second
  - data persisted in megabytes per second

- Scalability
  - number of client nodes
  - number of client workbenches

Test Criteria

- Reliability
  - program requirements for failover recovery
  - benchmark for current failover recovery

- Performance
  - benchmark of currently required processing units
  - program requirements for latency
  - benchmarks of current latency

- Scalability
  - benchmark of current number of clients
  - benchmark of current volume of data distributed
  - benchmark of current volume of data persisted

Technologies Tested

- JVM
  - computational performance

- JBoss Messaging
  - volume and latency of data distribution
  - failover of connections

- Hibernate/MySQL
  - volume and speed of data access
  - failover of data access

- JBoss AS
  - supported processing load
  - latency of processing steps
  - failover of processing

Test Architecture

Computational Load Modelling

- 1 work unit = 6 hour trajectory numerical integration
- total high speed processing in 62 work units

Processing Load Modelling

- computational load
- data access load
- messaging load

Testing Results

- Java Virtual Machine

  - algorithms complete is less than a fifth of the required time.
  - heap size stable during loading test
  - garbage collection consistent during testing
  - garbage collection does not impact latency of processing
  - Sun JVM proven to be most reliable
  - JRocket JVM generated segmentations faults

Testing Results

- JBoss MQ (example test case)

  - 4 node cluster running consecutively for 1 day
  - Continued for 5 more days with 3 node cluster
  - 28.5 million work units submitted to cluster
    - 3 sets of 20 work units submitted per second
    - Round-robin load balancing policy across cluster
  - 1.1 TB transferred, 2.4 MB/s average,
    - single HA Queue
  - Master node failure and recovery successful
    - Cause: inadvertent machine reboot

Testing Results

- JBoss Messaging (example test case)

  - Blade server with dual CPU
  - 2MB RAM for JBoss AS
  - 6 node cluster, 4 JBoss AS nodes, 2 MySQL nodes
  - 480 work units submitted to cluster per second
    - 3 sets of 40 work units to each JBoss AS node
    - Round-robin load balancing policy across cluster
  - 480 clustered database record merges per second
  - 480 JMS messages routed per second
  - Constant load for fifteen minutes
  - Consistent one second processing times for each one second batch of request

Testing Results

•Hibernate/MySQL

- Standard Java Application with clustered MySQL
  - 20 threads performing 25K transactions
  - 1800 inserts/sec using Hibernate
  - 2800 inserts/sec using JDBC

- Integrated JEE Application with clustered MySQL
  - greater than 1000 merges per second per node
  - greater than 1MB per second per node

Note: MySQL connection time limit is configurable, but connection time required during initial start up creates need for 10 sec timeout setting

Testing Results

- JBoss AS

  - supports number of required sequential pipe and filter style processing steps
    - individual filter steps include computational and persistent data access
    - individual pipe steps include messaging
  - support concurrent asynchronous processing load
  - supports processing load greater than 5 times need
  - processing state failover in less than 30 sec

Project Conclusions

- Java application computational performance is acceptable given the proper hardware resources.

- JEE specification and supporting technologies can be used as a platform for mission critical operations.

- Open Source implementations of JEE, such as JBoss Enterprise Application Platform, are a viable alternative to custom enterprise solutions.

- NASA could elect to focus it's expertise on aerospace solutions and reuse existing open source middleware solutions.

Next Steps

- Explore Additional Technologies
  - Web Services
    - to expand access to business components to non Java clients
  - Enterprise Service Bus
    - to expand interoperability with external systems
  - Business Process Management
    - for orchestration of business workflows
  - Rich Client Platform
    - to integrate and manage side client components