# Applying Model-Integrated Computing & DRE Middleware to High-Performance Embedded Computing Applications

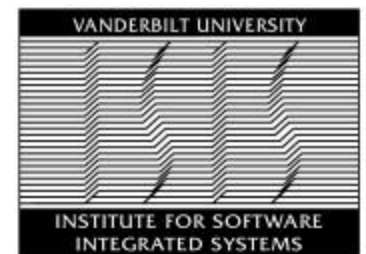Douglas C. Schmidt          (schmidt@uci.edu)
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HPEC'02 Workshop

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# Motivation

**Context**

- HPEC systems are widely used for signal & image processing applications with stringent QoS distributed real-time & embedded (DRE) requirements

**Problem**

- Due to weight, power, real-time, & footprint constraints, HPEC software has not traditionally been able to leverage advances in COTS middleware
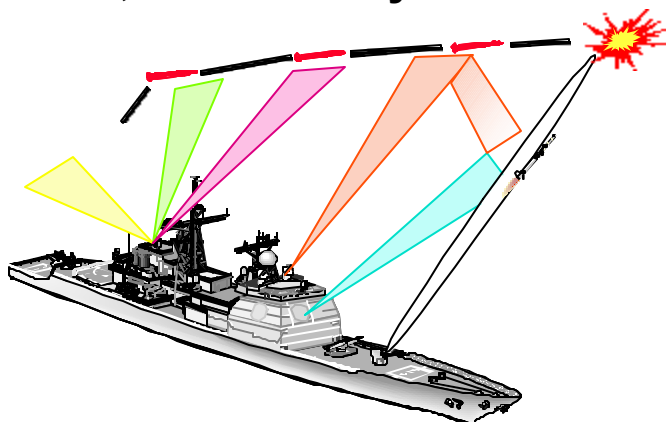
**Promising Solution**

- Use standards-based **DRE middleware supporting multidimensional QoS properties** (RT-CORBA, DP-CORBA, load balancing)
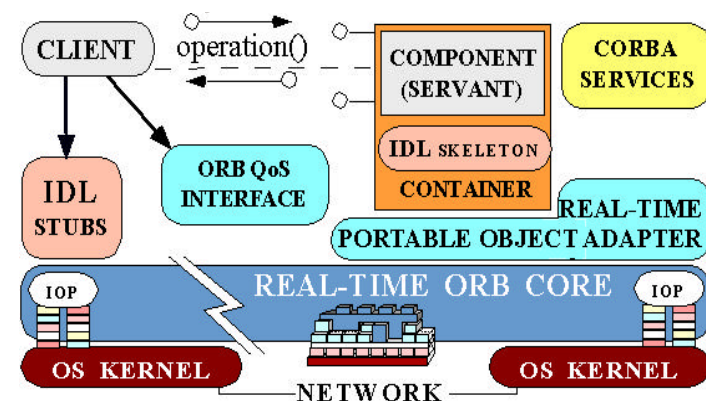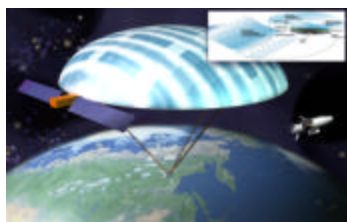
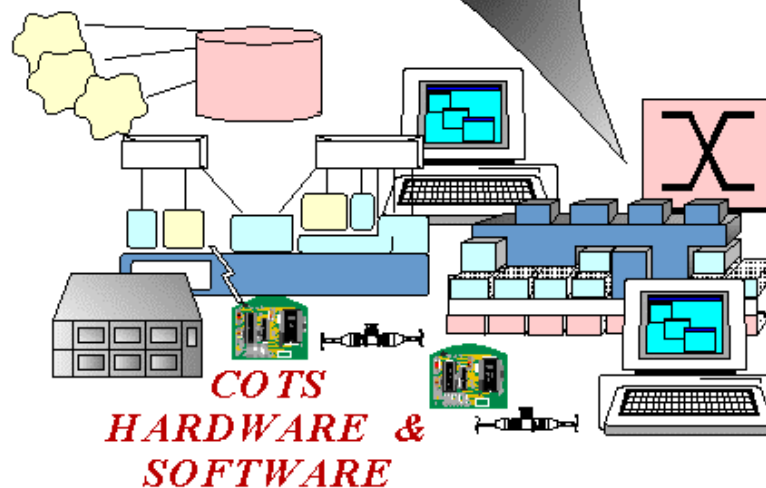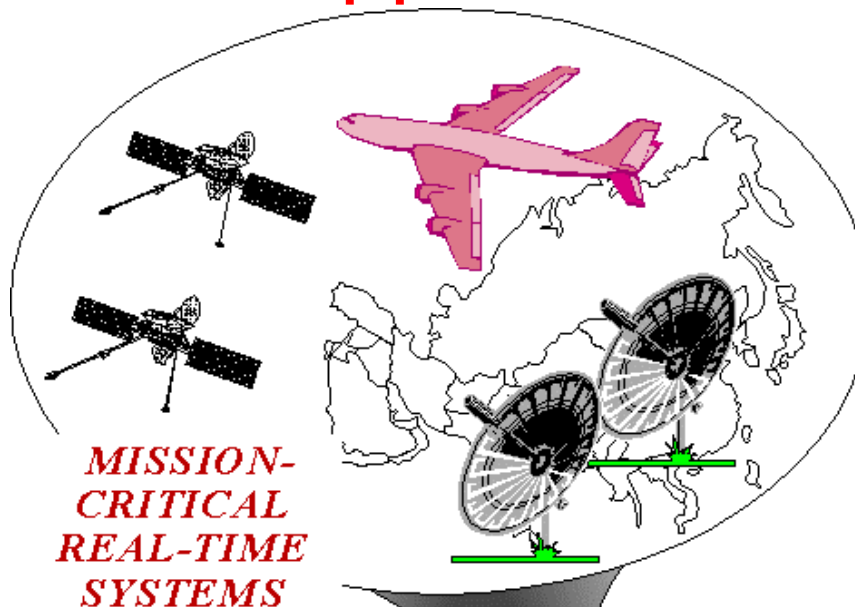# DRE Middleware in HPEC Applications

**High-performance, real-time, fault-tolerant, & secure systems**
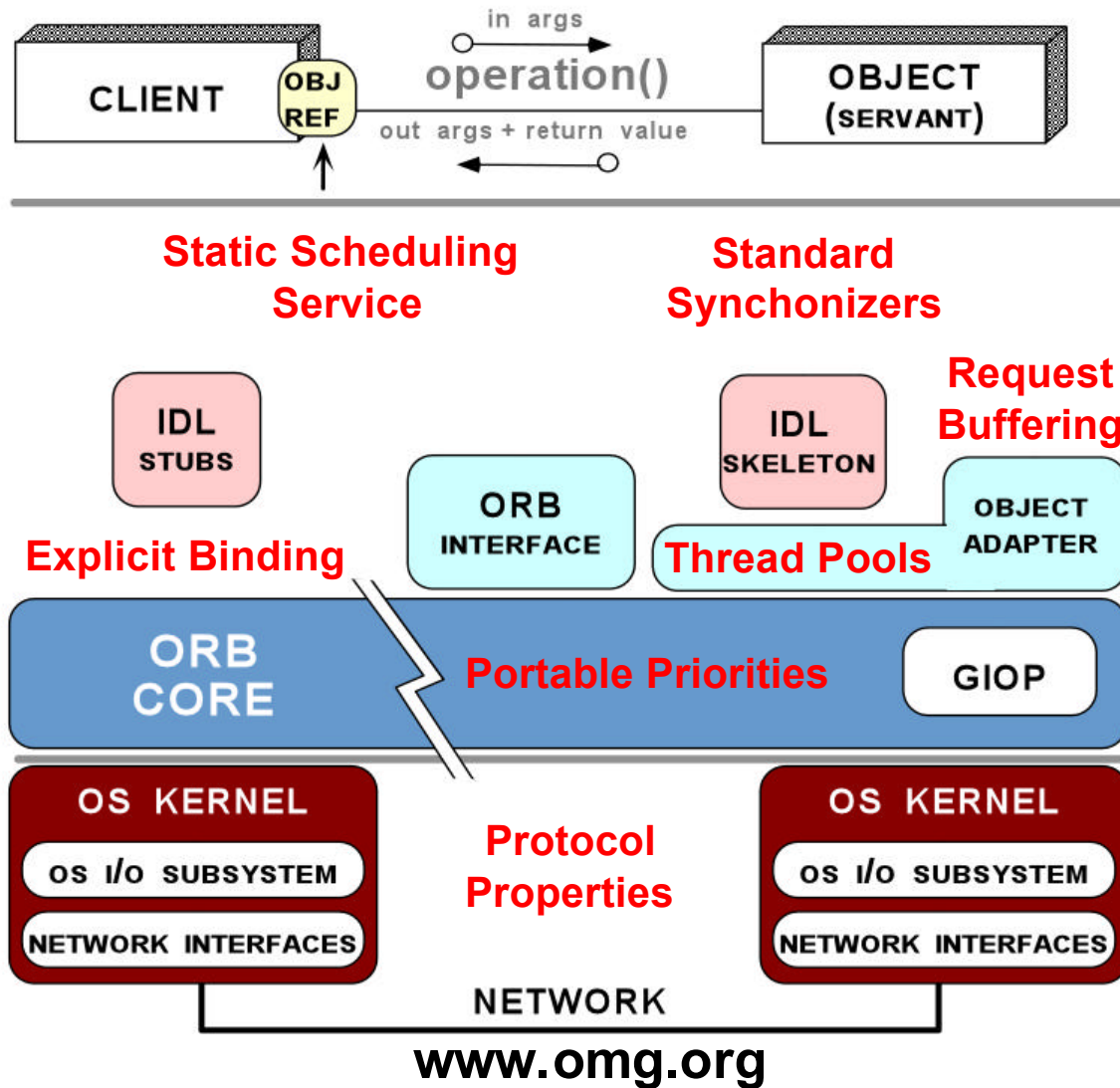
**Autonomous distributed embedded systems**

**Power-aware *ad hoc*, mobile & embedded systems**

MISSION-CRITICAL REAL-TIME SYSTEMS

COTS HARDWARE & SOFTWARE

# DRE Middleware: RT CORBA Overview

**Client Propagation & Server Declared Priority Models**



**Static Scheduling Service**   **Standard Synchonizers**

**Explicit Binding**   **Request Buffering**

**Thread Pools**

**Portable Priorities**

**Protocol Properties**

**www.omg.org**

- CORBA is a middleware standard
- Real-time CORBA adds QoS to classic CORBA to control:

1. **Processor Resources**
   - Thread pools
   - Priority models
   - Portable priorities
   - Standard synchronizers
   - Static scheduling service

2. **Communication Resources**
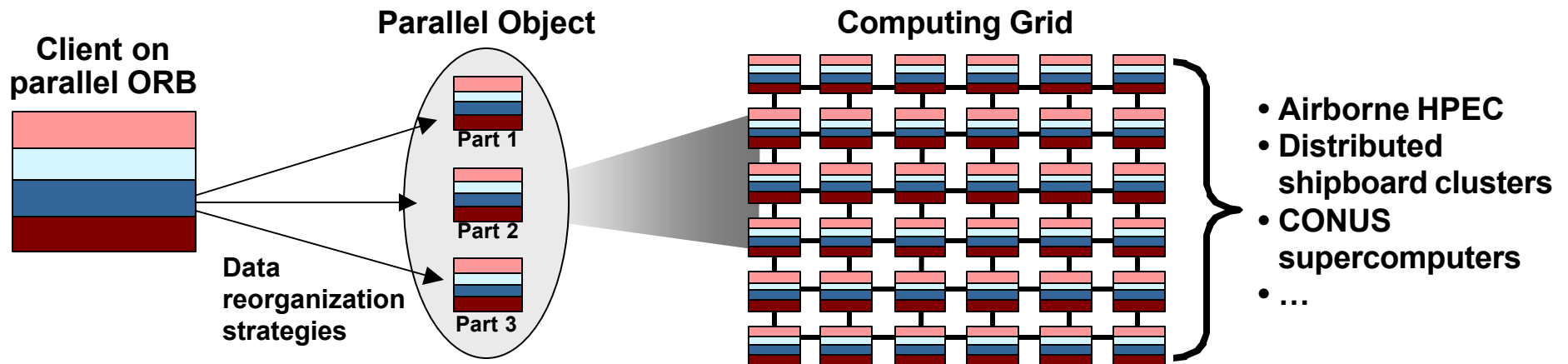   - Protocol policies
   - Explicit binding

3. **Memory Resources**
   - Request buffering

- These capabilities address some (but by no means all) important HPEC application development & QoS-enforcement challenges

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# DRE Middleware: Data Parallel CORBA

**Client on parallel ORB**

**Parallel Object**

**Computing Grid**

**Part 1**

**Part 2**

**Part 3**

**Data reorganization strategies**

- Airborne HPEC
- Distributed shipboard clusters
- CONUS supercomputers
- …

***Data Parallel CORBA*** bridges the gap between traditional CORBA applications & high-performance embedded parallel processing applications as follows:

- Enable CORBA applications over clusters of computers
- No change required in software technologies, methodologies, or tools
- Enable massively parallel applications to integrate easily with distributed systems
- Allow parallel applications to benefit from distributed object methodologies, technologies, & tools
- Add parallelism & data distribution to the transparencies offered by CORBA
- Enable a new class of applications *e.g.*, financial, industrial, medical, aerospace, multimedia, and military domains

# Problems with Standard DRE Middleware

## Too many "standards"

- Proliferation of middleware technologies – *CORBA, Java EJB/RMI, COM+/.NET*
- No one-size-fits all
- Accidental complexities assembling, integrating & deploying software systems
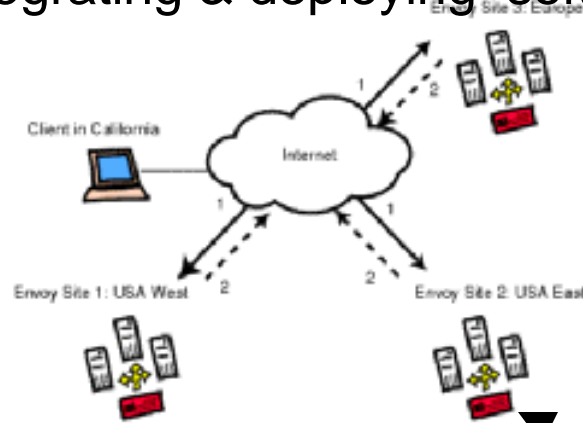
## Lack of coordination in standards committees addressing multiple QoS properties
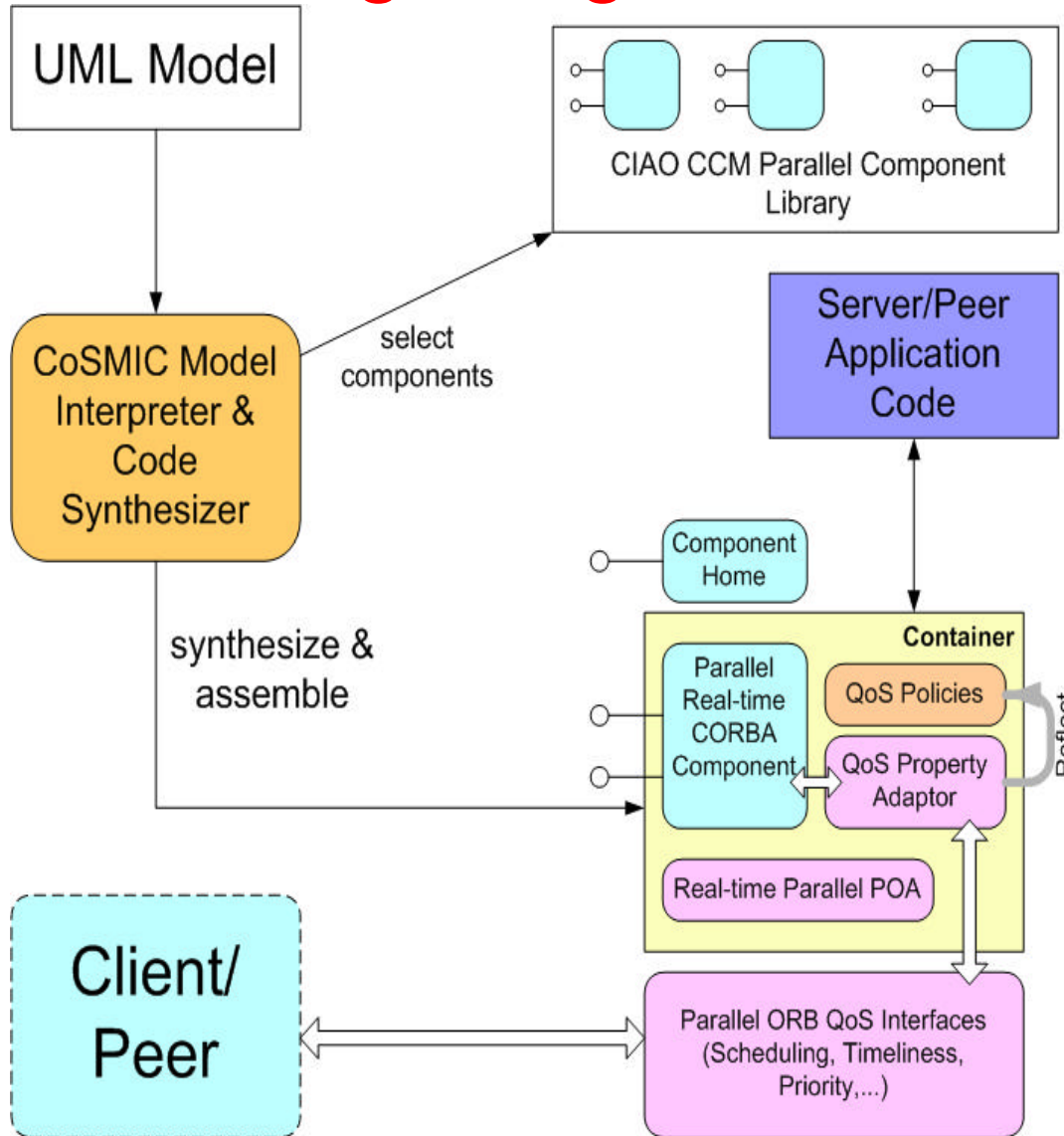
- Several independent standards each addressing a single dimension of QoS
  - e.g., Real-time CORBA, Fault tolerant CORBA, Load Balancing, Data Parallel CORBA, etc.

## Promising Solution

- Integrate **Model-Integrated Computing** & the OMG **Model Driven Architecture** with **Multi-QoS DRE middleware**

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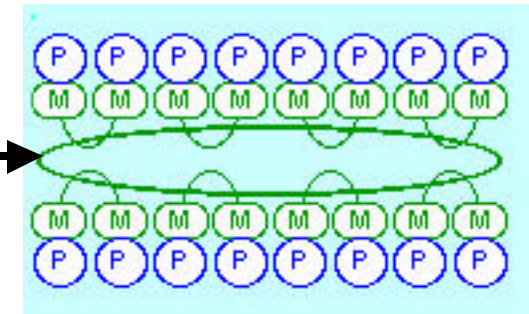
# Integrating MIC with DRE Middleware



**Proliferation of middleware**
- UML modeling tools used to model DRE application behavior
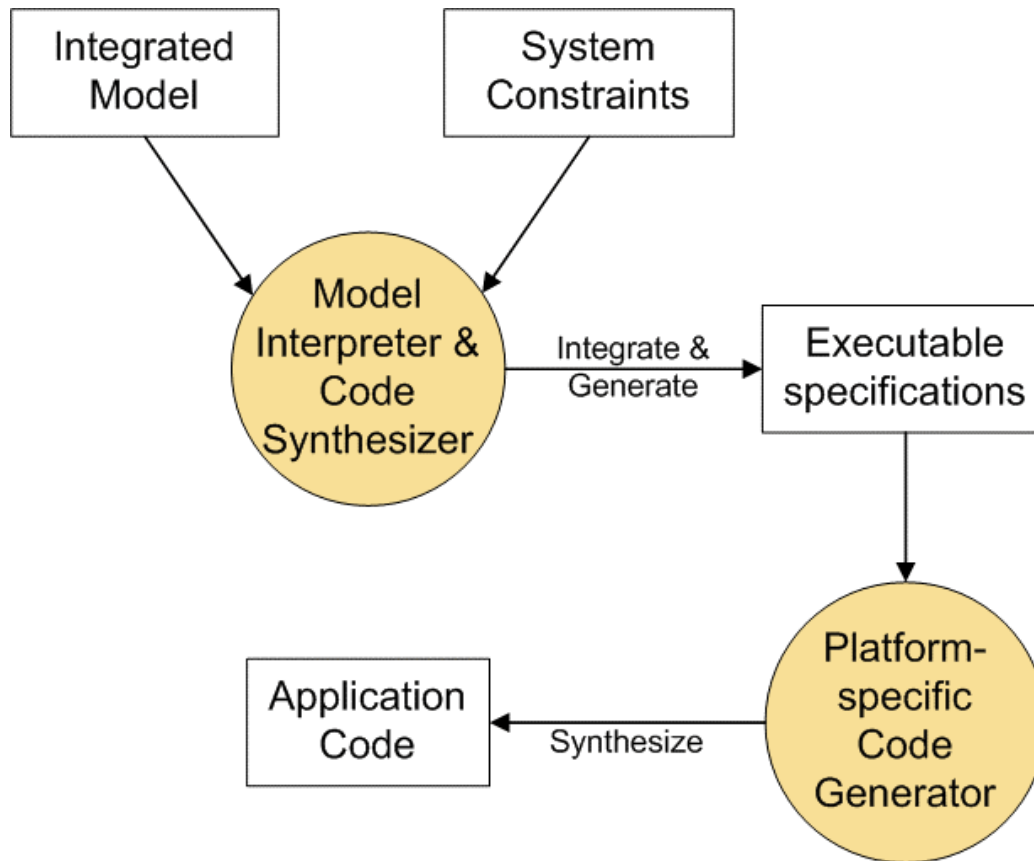- Model-first/generate-next strategy for finer grained control in components

**Simultaneous support for multiple QoS dimensions**
- Model overall application QoS & partitioning
- Compose application servers
- Model & synthesize components
- Validate & deploy

**Accidental Complexities**
- Synthesize container QoS configurations & metadata

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# Model-Integrated Computing (MIC) Overview

Integrated Model

System Constraints

Model Interpreter & Code Synthesizer

Integrate & Generate

Executable specifications

Application Code

Synthesize

Platform-specific Code Generator

- **Analyze** – different but interdependent characteristics of DRE system behavior
- **Synthesize** – platform-specific code customized for DRE application

- Applies domain-specific modeling languages to computing systems
  - Provides rich modeling environment including model analysis & model-based program synthesis
  - Modeling of integrated end-to-end view of applications with interdependencies
  - Modeling languages & environments themselves can be modeled as meta-models
  - *Examples*
    - Generic Modeling Environment (www.isis.vanderbilt.edu)
    - Ptolemy (www.eecs.berkeley.edu)
- Based on DARPA MoBIES program

# Model Driven Architecture (MDA) Overview
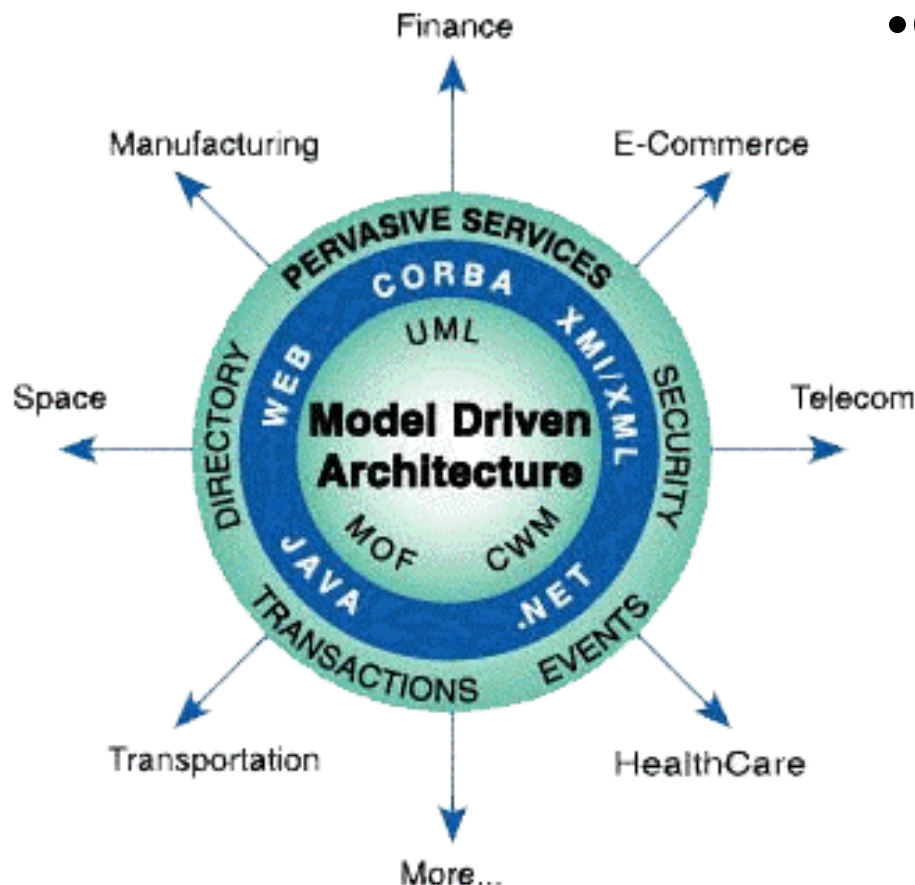


www.omg.org/mda

- OMG standardization of MIC paradigm
  - Defines platform- independent models (PIMs) and platform-specific Models (PSMs)
  - Uses Unified Modeling Language (UML) for modeling
    - Real-time profile
    - Dynamic scheduling profile
  - Meta Object Facility (MoF) serves as meta-model repository
  - XML Metadata Interchange (XMI) for meta-model exchange
- Efforts are underway to integrate DARPA MoBIES/MIC with OMG MDA
  - Contact John Bay <jbay@darpa.mil>

# Component Integrated ACE ORB (CIAO)

## CCM incarnation of TAO Real-time ORB



deuce.doc.wustl.edu/CIAO
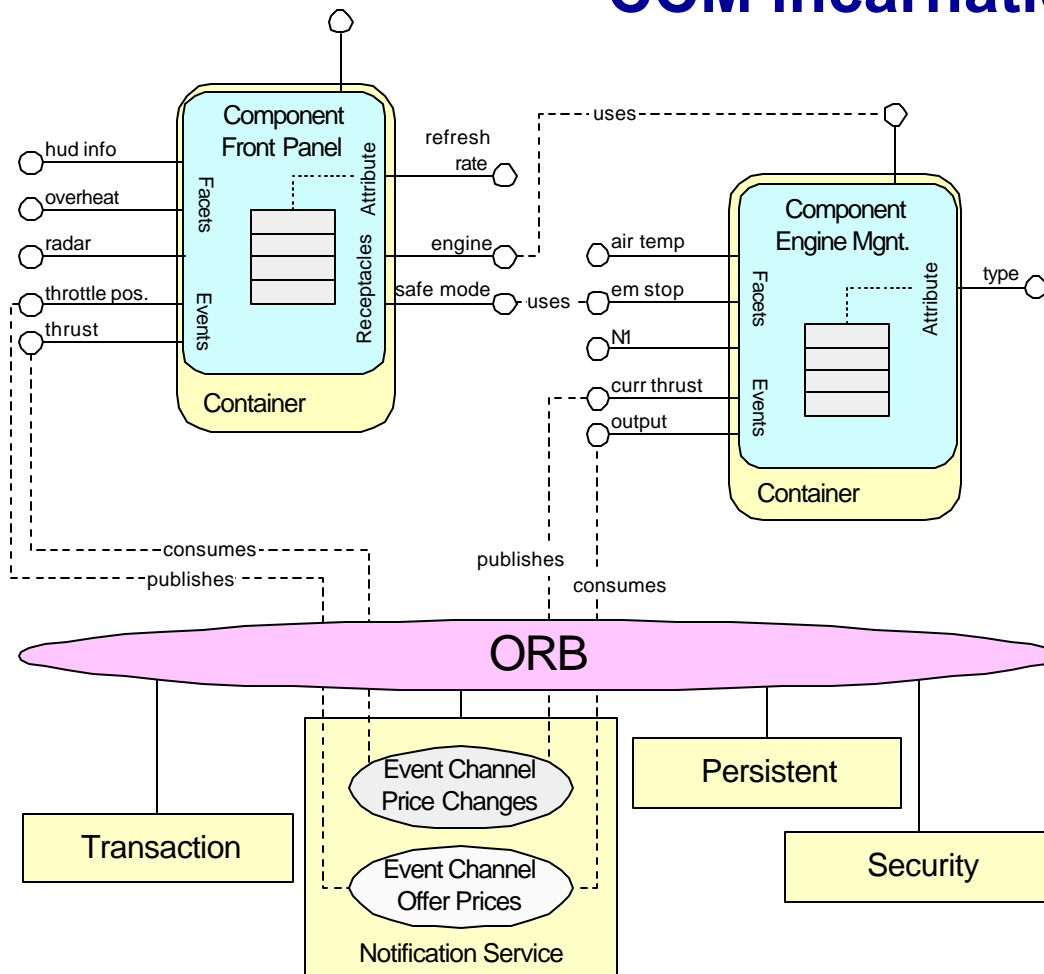
- Support development via composition
  - Providing CCM framework
- QoS-aware
  - Decouple QoS policies specification from component implementations
  - Specify QoS policies in component assembly descriptors
- Configurable
  - Leveraging hardware capabilities
  - Composing QoS supporting mechanisms for CCM application servers

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# Integrating DP-CORBA & Load Balancing



## Meta Resource Broker
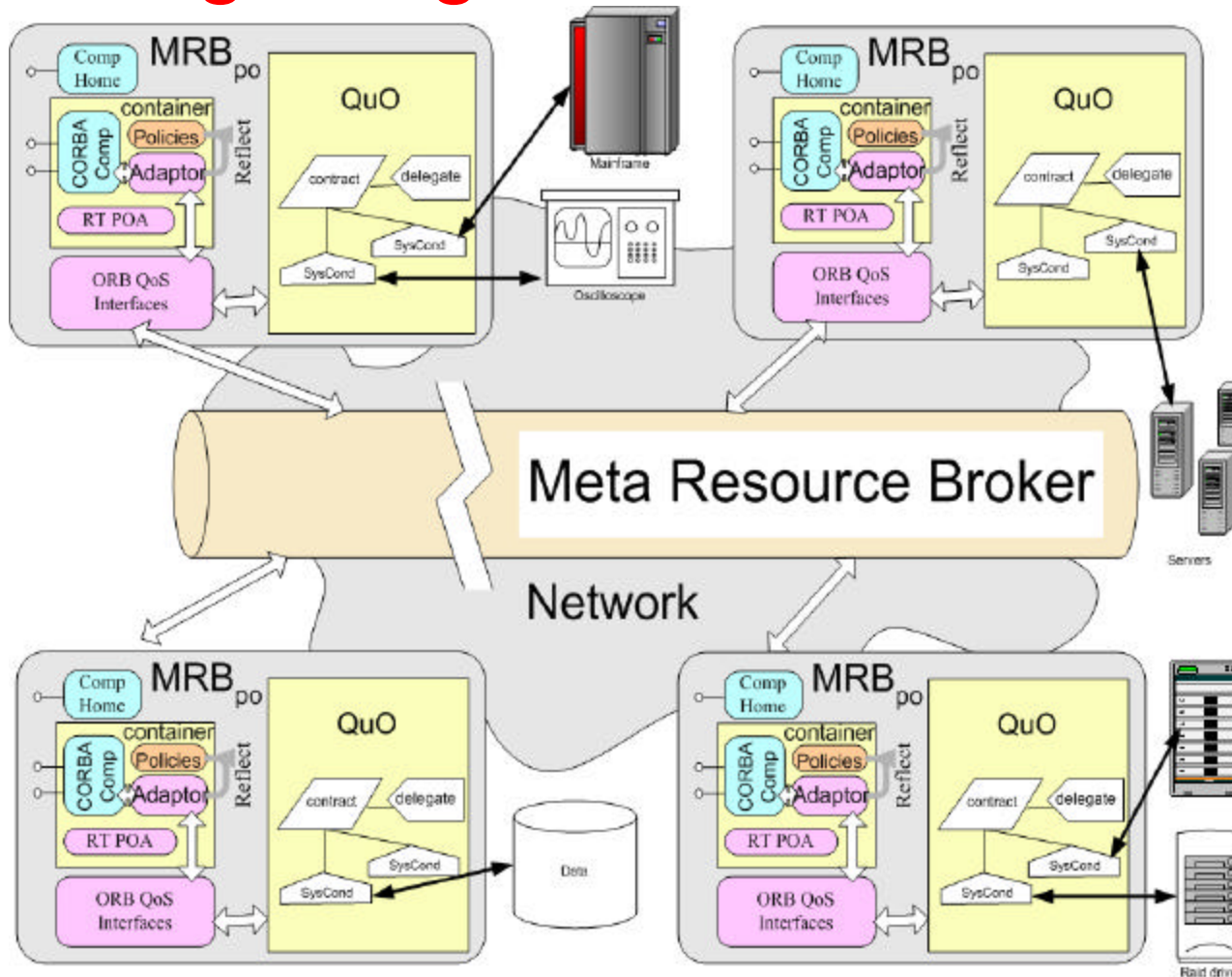
- DP-CORBA incarnation of TAO
- Broker for resources
- Maintains abstractions of concrete resources & their usage
- Uses DP-CORBA to partition data
- Uses TAO load balancing service to make optimal use of resources

•QuO (quo.bbn.com) provides flexible QoS management

•MRB uses QuO for QoS monitoring and adaptation

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# Component Synthesis with MIC (CoSMIC)
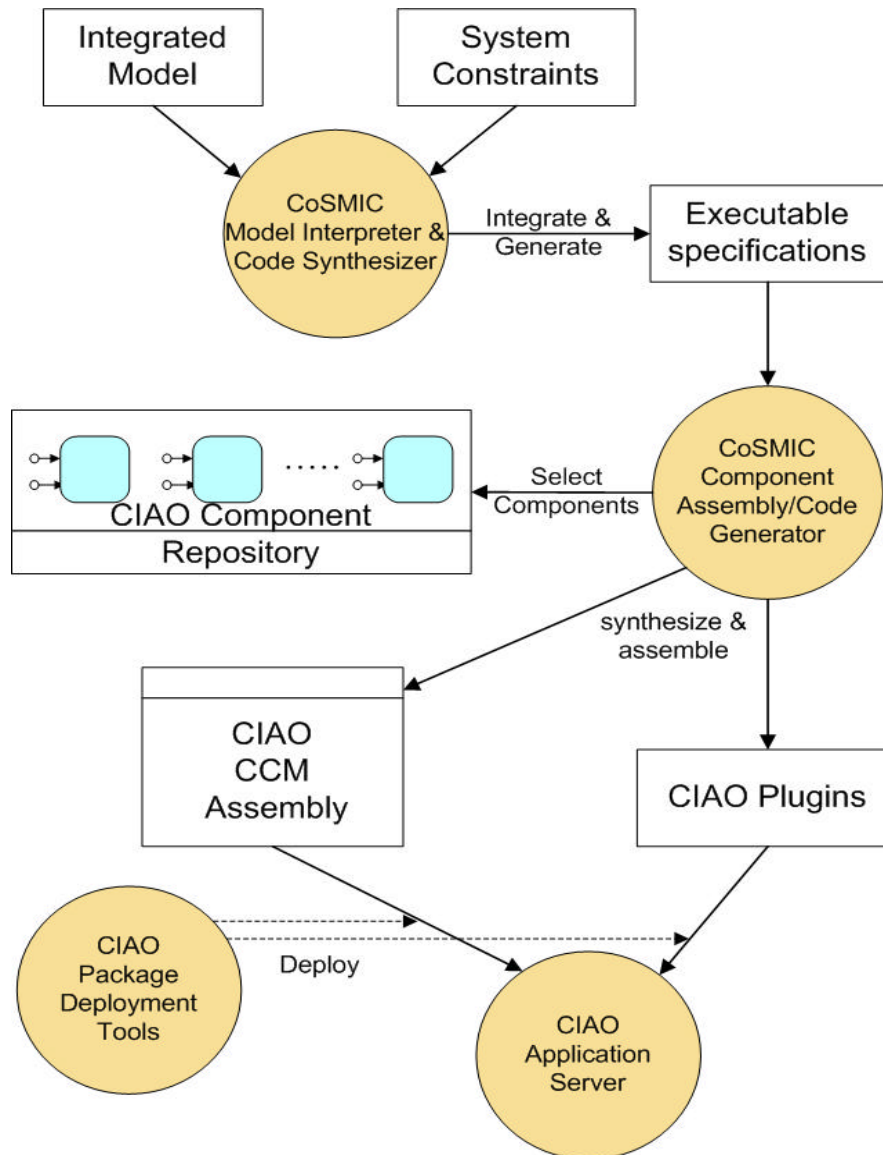


- Synthesizes code & configuration metadata for the CIAO CORBA Component middleware
  - Reusing components via compositions vs. generating new component implementations
  - Composition of applications components & CIAO plug-ins
  - CIAO helps instantiating application processes
- MDA tool suite
  - UML modeling using GME
  - Analysis & synthesis tools
  - Enhancement to GME tool
  - Uses MDA standards-based approach
- DARPA PCES program seeks solutions to integrate MIC with DRE Middleware
  - Contact Douglas Schmidt <dschmidt@darpa.mil>

# Summary of Ongoing Work
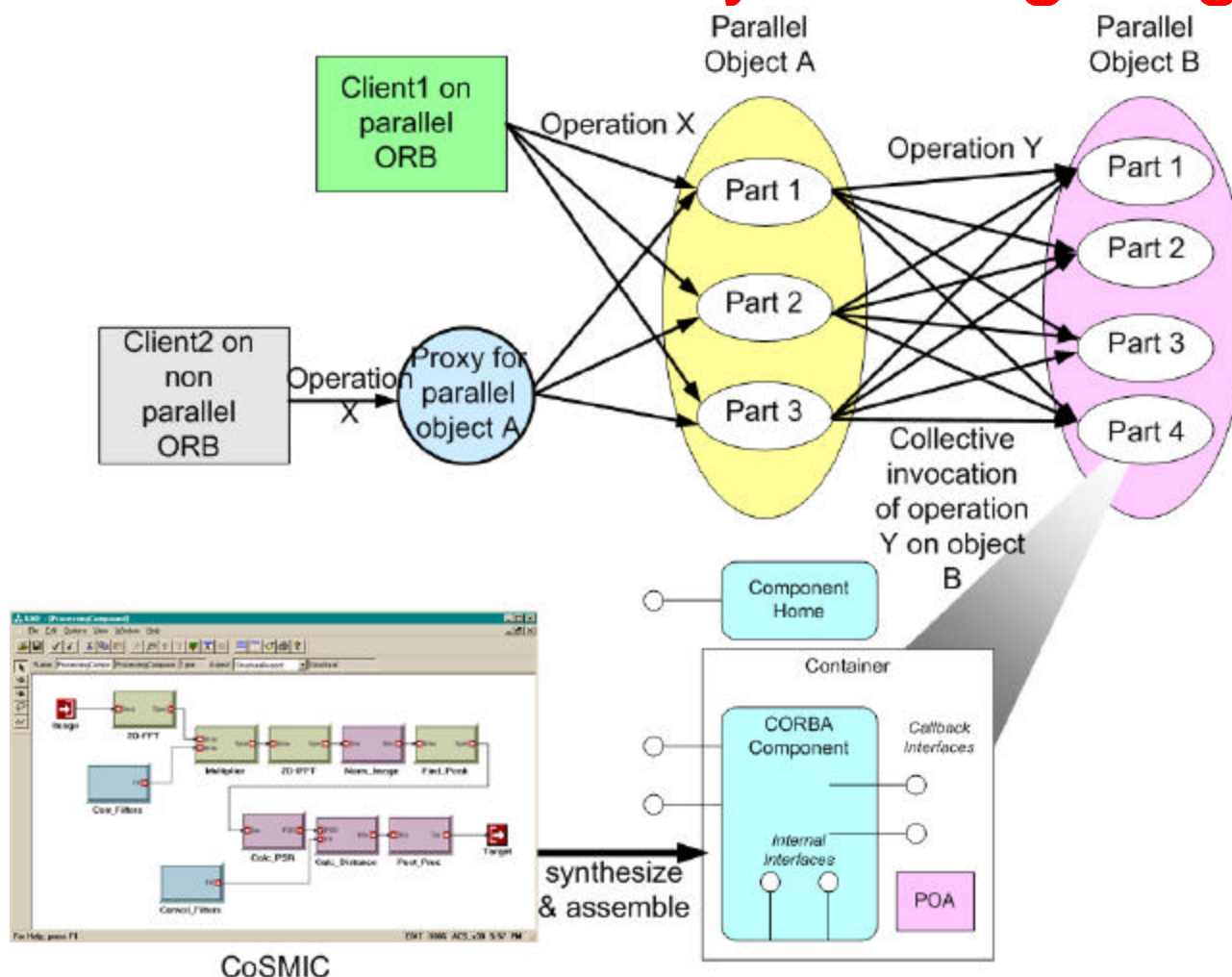


CoSMIC

- RT/CCM (CIAO) being implemented at Washington University & Vanderbilt University
- DP-CORBA being implemented jointly between Vanderbilt University & UC Irvine
- CoSMIC tool suite, MRB being developed at Vanderbilt University
- All results will be available as open-source software

**deuce.doc.wustl.edu/CIAO**
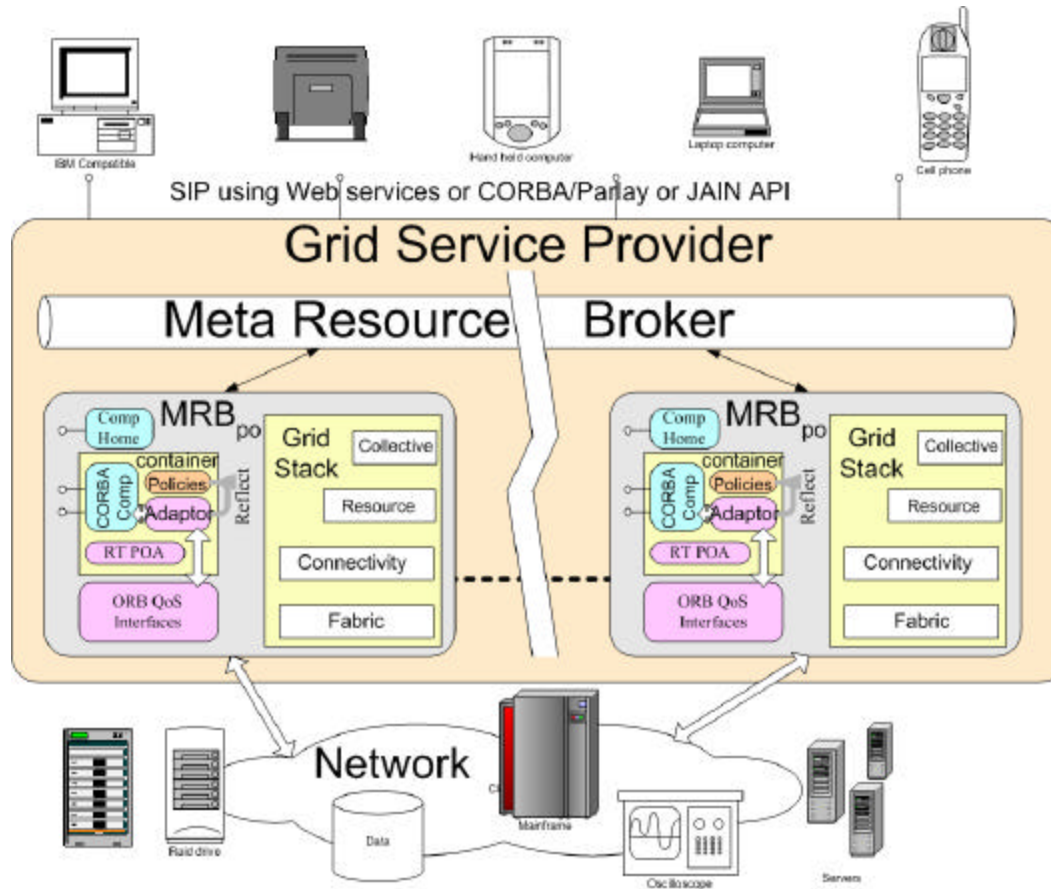**www.isis.vanderbilt.edu/{CoSMIC,DP-CORBA}**

# Benefits of Integrating MIC & DRE Middleware
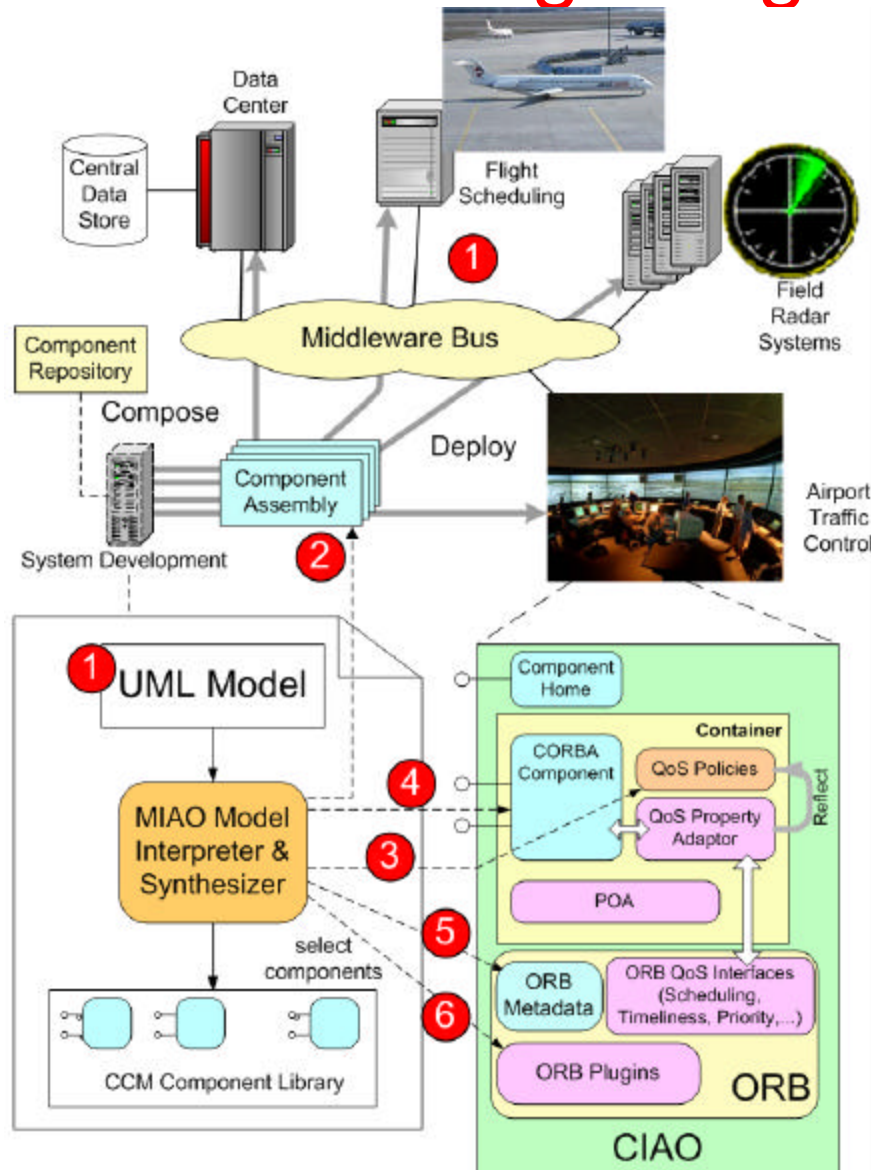


- Large portions of application code can be composed from prevalidated, reusable middleware components.

- Helps in the rapid assembling and deployment of applications in the face of changing business or government rules and procedures.

- Makes middleware more robust by automating the configuration of QoS-critical aspects, such as concurrency, distributions, security, and dependability

- MIC helps bridge the interoperability problems between different middleware for which no standard solutions exist.

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# DRE Middleware Relationship with HPEC GRID



SIP using Web services or CORBA/Parlay or JAIN API

Grid Service Provider

Meta Resource Broker

**Grid Characteristics**

- Simultaneous multiple QoS properties
- Multiple resources from multiple providers
- **Middleware Examples**: Globus, ICENI, Legion

**Grid Challenges**

- Tight coupling with grid infrastructure middleware (GIM)
- Accidental complexities of assembling & deploying grid applications
- Difficulties in resource & QoS assurance

Applying Standard Real-Time & Data Parallel CORBA Enhances HPEC
- Extends Current Grid Capabilities
- Leverages Model Integrated Computing

# Concluding Remarks
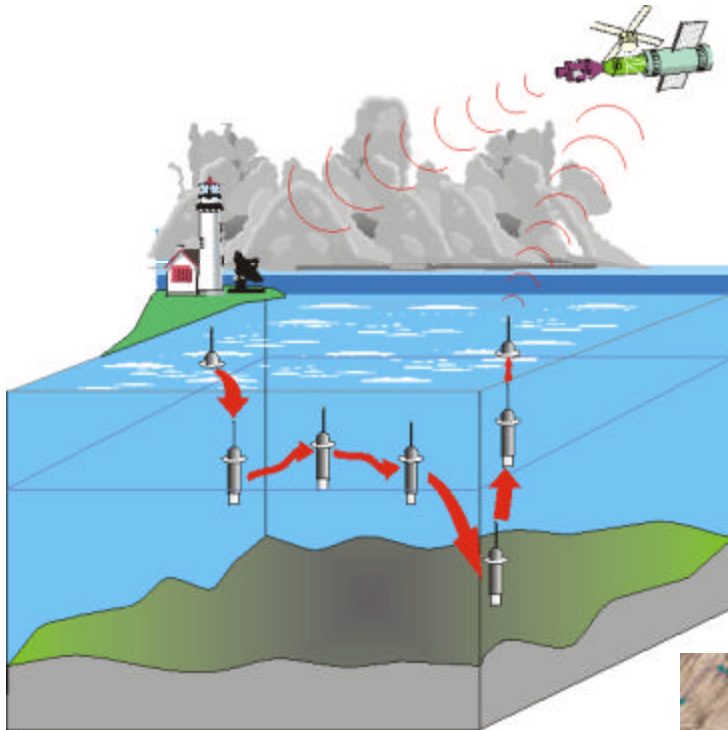
- DRE application development challenges resolved by combining MIC/MDA & QoS-enabled component middleware

- The CoSMIC & CIAO projects are applying MIC/MDA to support DRE CORBA-based HPEC applications

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