OMG's 2nd Workshop in Real-Time and Embedded Distributed Object Computing

CORBA in SIGINT Systems
A Case Study

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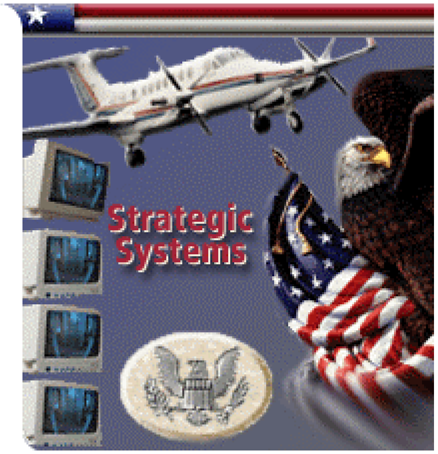
Agenda

- Who is Raytheon?
- Terminology
- Legacy System Architecture
- Next Generation Sensor System Diagram
- Why CORBA?
- Next Generation Sensor System Architecture
- Sensor System Characteristics
- Example: Applications Loader
- Sensor System CORBA Usage
- Lessons Learned
- Concluding Remarks

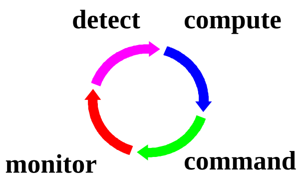
Who is Raytheon?

- Headquartered in Lexington, Massachusetts
- Celebrated Its 79th Anniversary This Year
- $20+ Billion Global Technology Leader
- 105,000+ Employees World-wide
- Operates in Three Business Areas
  - Commercial Electronics
  - Aircraft
  - Defense Electronics
- C^{3}I and Information Systems
  - providers of information to the warfighter

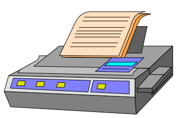


http://www.raytheon.com

Terminology

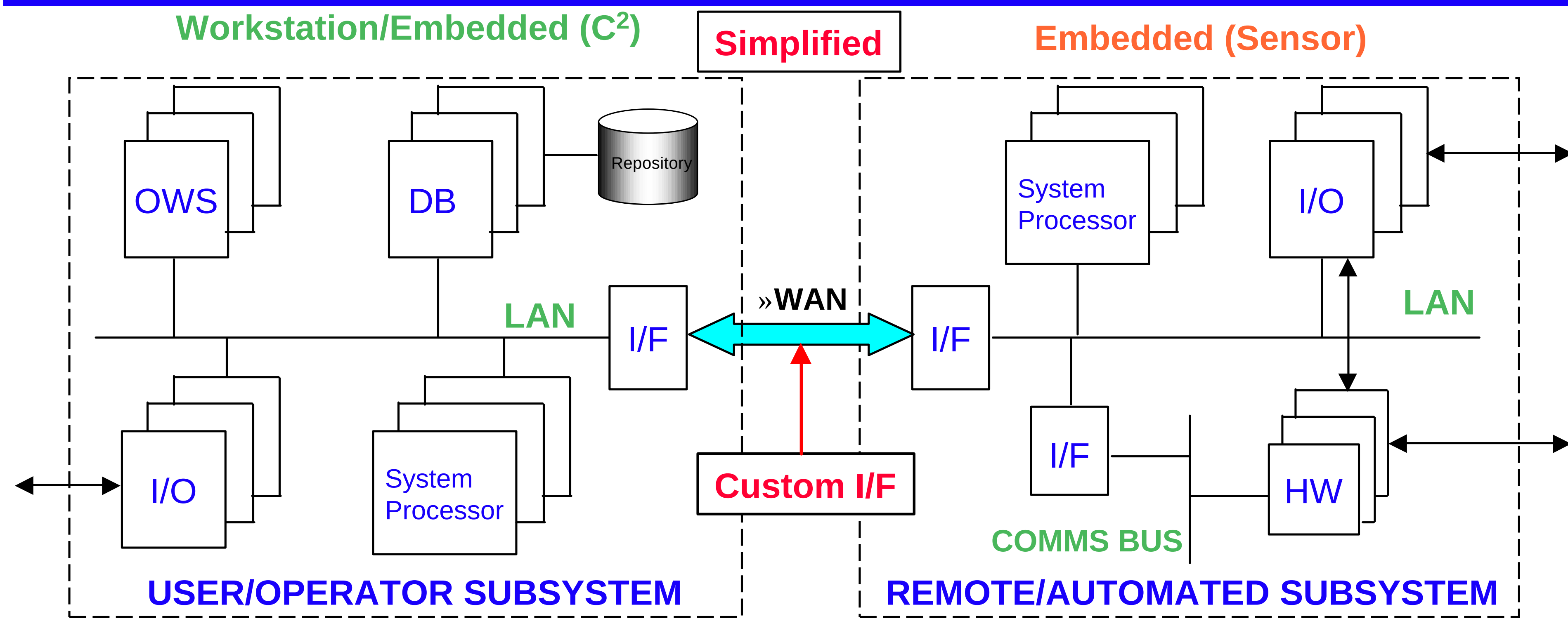


➢ Real-Time - an on-line computer processing system that receives and process data quickly enough to produce output to control, direct, or effect the outcome of an ongoing activity.



➢ Embedded System - computers that are built into a product and whose prime function is not that of a computer.

Legacy System Architecture



Sensor:

3 General Purpose Processors - mostly C language

20 Embedded processors/controllers

various types and capabilities

custom hardware and software - few commercial stds

Few COTS items (hardware and software)

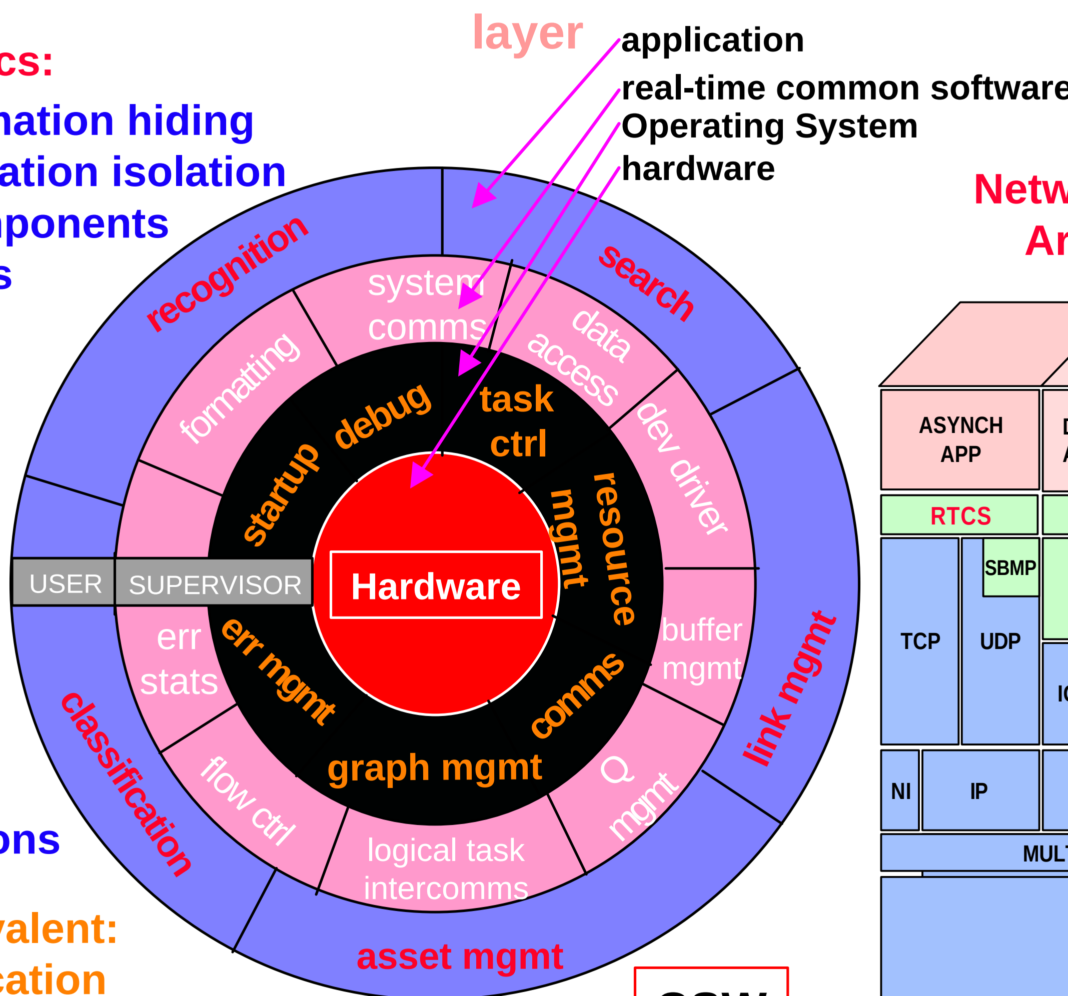
- **Architecture:**
  - physical-functional organization
  - not distributed, "stove piped"
  - not based on a framework
  - message passing based
  - message API on-top of sockets layer
  - "closed"

Common Software Framework

TRADITIONAL METHOD

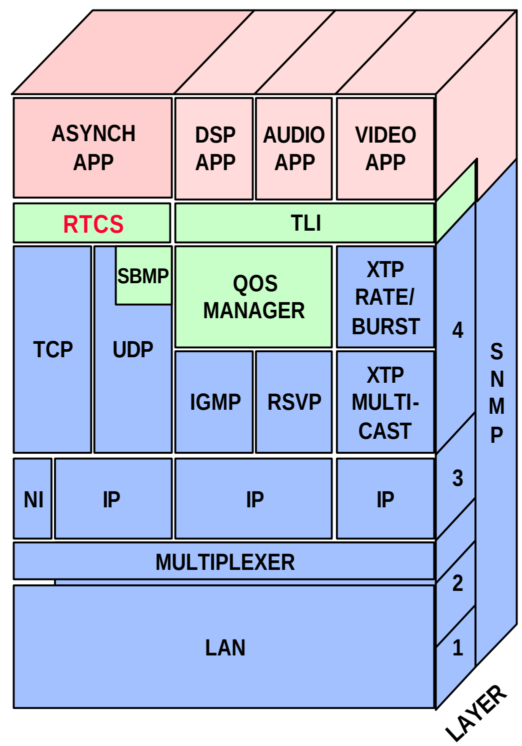
Key Characteristics:

provides layered information hiding
- implementation-application isolation
- supports reuse of components
- separation of concerns
- provides abstraction
- extended services
- protected access
- common functions available applications
- network isolation
- Real-Time and UNIX platform support
- proven technology
- provides platform portability to applications



CSW

Network Protocol Architecture



Open Source Equivalent: Adaptive Communication Environment (ACE)

Legacy Software Middleware

Software Characteristics

- Message Passing Concept
  - client-server exchange messages
  - events generate messages
- Message Limitations:
  - encoded bits
  - language implementation specific
  - interface not clearly defined
  - numerous messages
  - request/response not identifiable
- **Interface Limitations**:
  - not structured
  - not clearly defined
  - language dependent
  - no O-O concepts utilized
- Somewhat platform/tool dependent
- tweaked to platforms

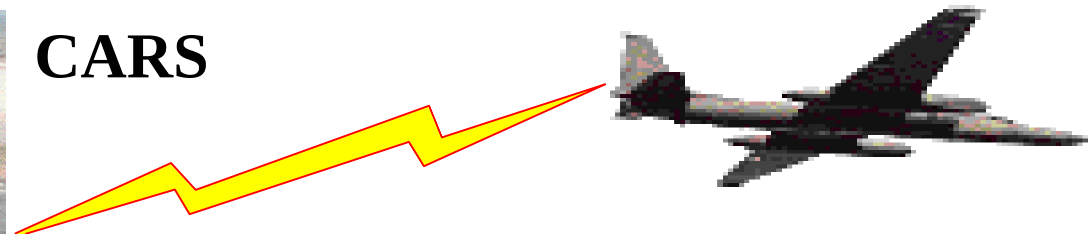
Message Format (simplified)

Word	
1	Message Identifier
2	Source Identifier
3	Destination Identifier
4	Message Length
	Data Word 1
	. . .
M	Data Word N

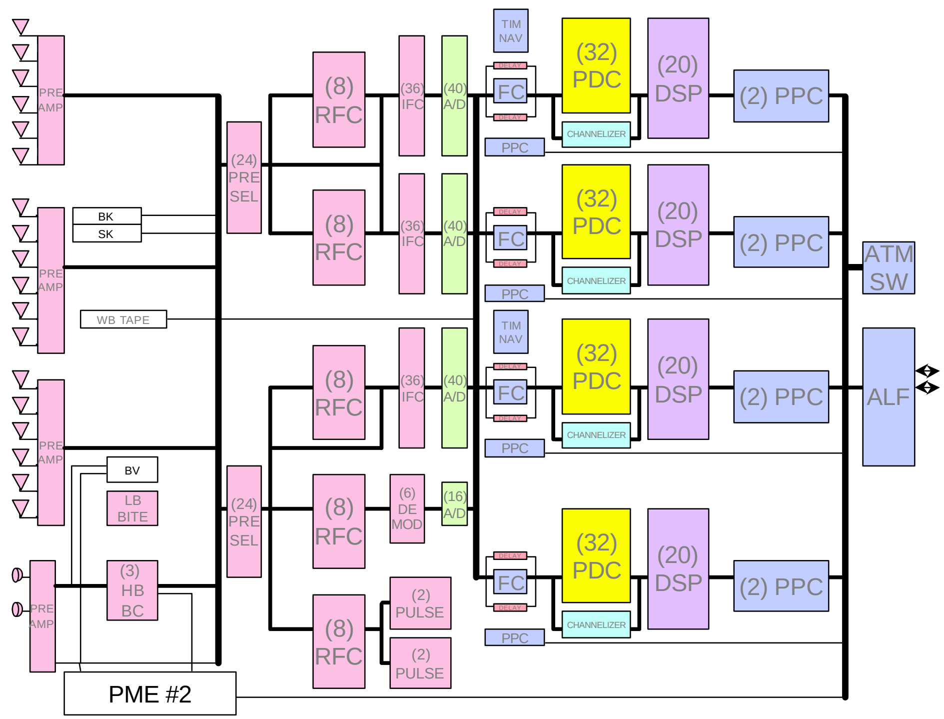
0 <---------- bit number ----------> 15

Next Generation Sensor System Diagram

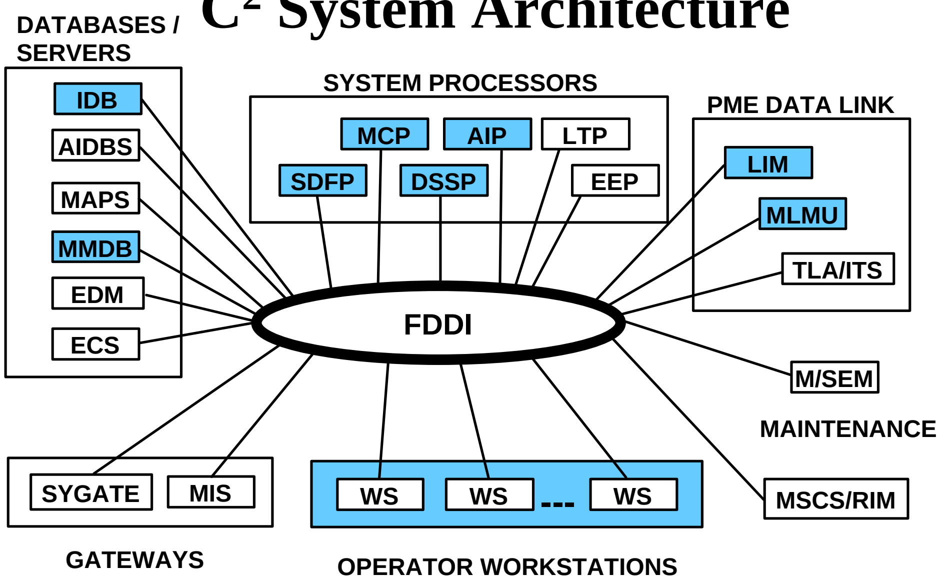
CARS



Sensor Architecture



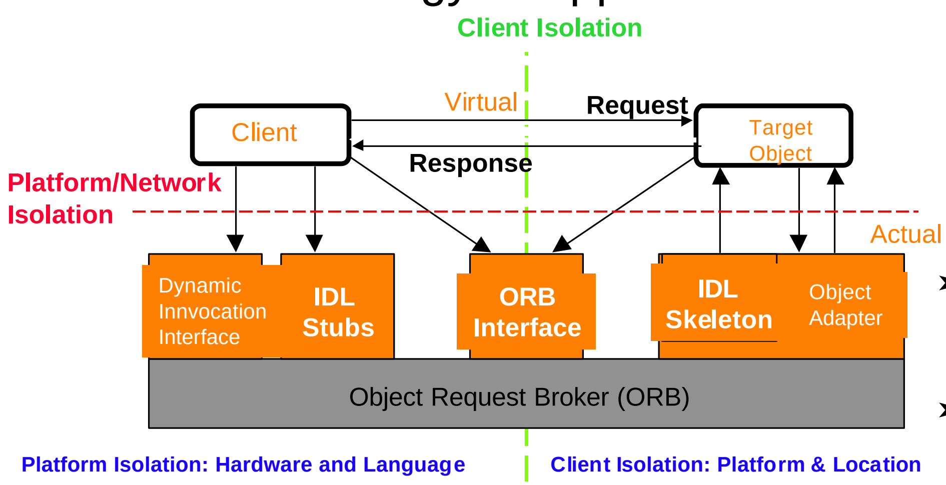
C^2 System Architecture



Why CORBA?

Sensor System Development Goals:

- Open Architecture; Well Defined I/Fs
- Scaleable to Meet User Requirements
- Software Re-programmable
- Leverage COTS
- Utilize Commercial Standards
- Legacy System Compatibility
- Platform (HW & SW) Independence
- Match Technology to Application



Rationale

- C^2 System and Sensor are distributed software systems: A number of applications executing on different processors and software environments
- Need to have a simple, transparent, uniform, and common method for these applications to communicate with each other efficiently and effectively
- **CORBA (a Commercial standard) provides this inter-application communication solution at the application [interface] and not at the network (sockets) level**
- Numerous Commercial and Public Domain CORBA Implementations exist
- *was really the next logical evolution*!

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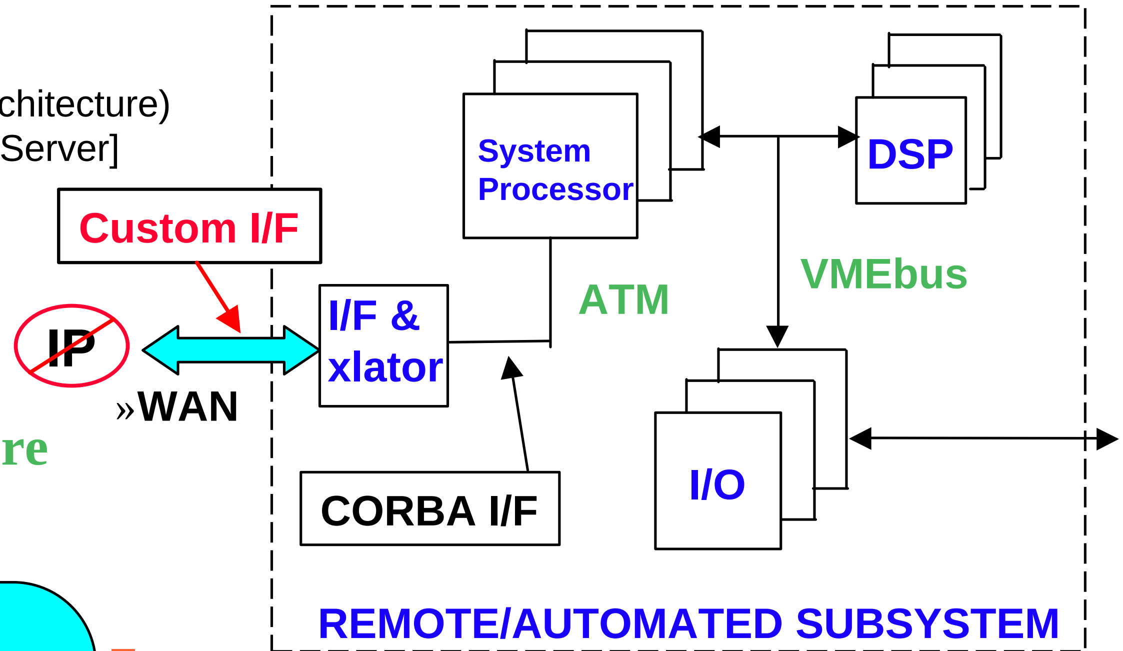
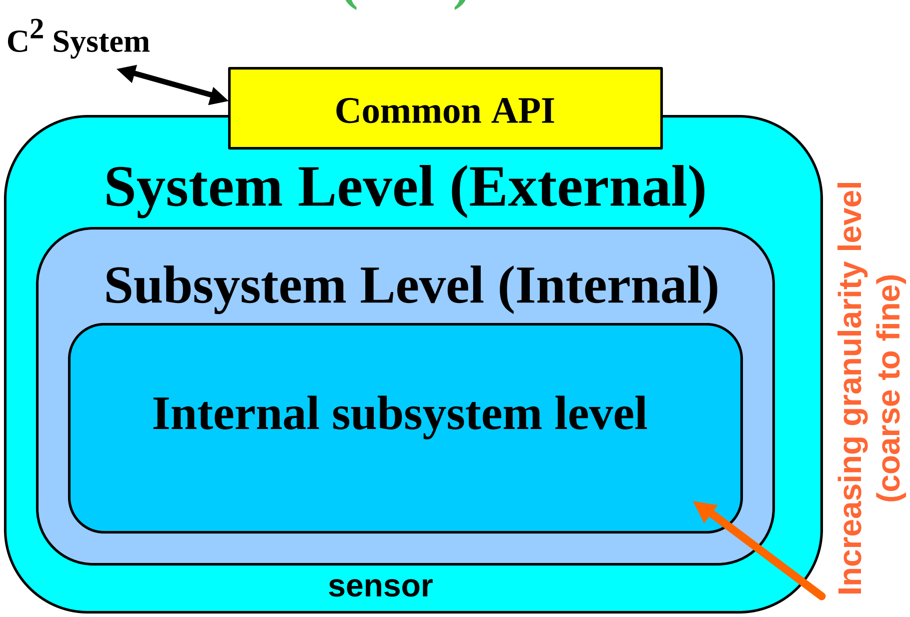
Next Generation Sensor Software Architecture

Key Software Characteristics

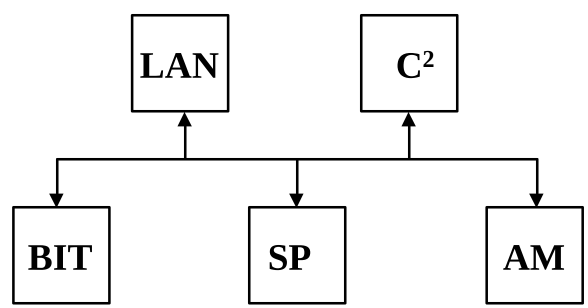
- CORBA Interfaces Levels (Hierarchical Architecture)
- Command and Control (C^2) Based [Client-Server]
- Distributed Object-Oriented Architecture
  - Thread versus Structured
- Configuration Driven for Scalability
- Separate Command and Data Paths
- Interoperability



Interface (IDL) Architecture



Software Object Categories



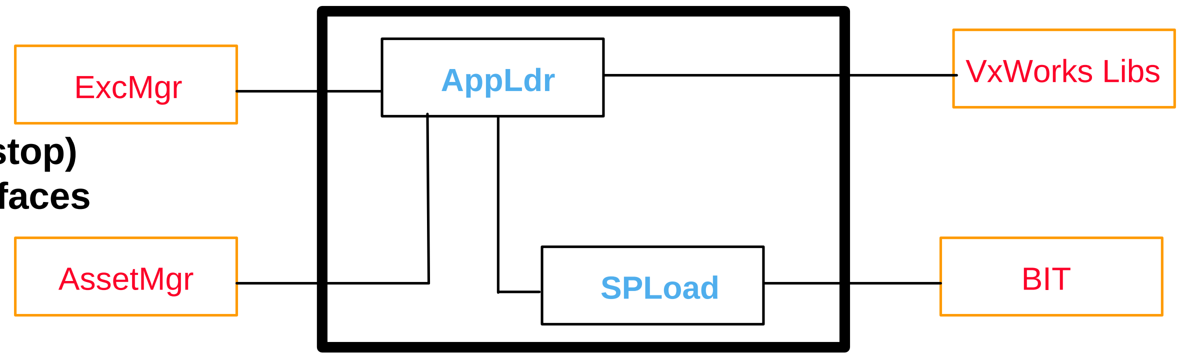
Sensor System Characteristics

- Embedded, Remotely Controlled, Instrumented, Heterogeneous Environment, Complex
  (C++ & IDL, C; 12-604 PowerPCs [200MHz] and 116-32040 DSPs; ~CORBA 2.0)
  System architecture is not a database centric model (no DB present in system)
  Locally distributed (close proximity) Clients and Servers
- Deterministic threads/paths: C^2 (i.e., signaling) and data (distribution & processing)
- Hard Real-Time (non-CORBA)
  - Sensor data manipulation and distribution (ex: streaming)
  - internal and external sources and destinations
  - latency < 1 uSec; throughput @ 10's M bps
- Near Real-Time (CORBA)
  - IDL for all system, subsystem and internal subsystem C^2 functions
  - IDL organized in a hierarchical level with degrees of granularity
  - latency < 100 mSec for time-critical threads and events
  - majority of client-server relationships are one-to-one
  - 8 main system level interfaces expressed in IDL; total of 16 system level interfaces functional threads; @ 5k lines of IDL and @ 500k SLOC code (C & C++)
- Organization
  - System Level - Entire Sensor is a Server (multiple categories of services)
  - Internally - CORBA based-clients and servers

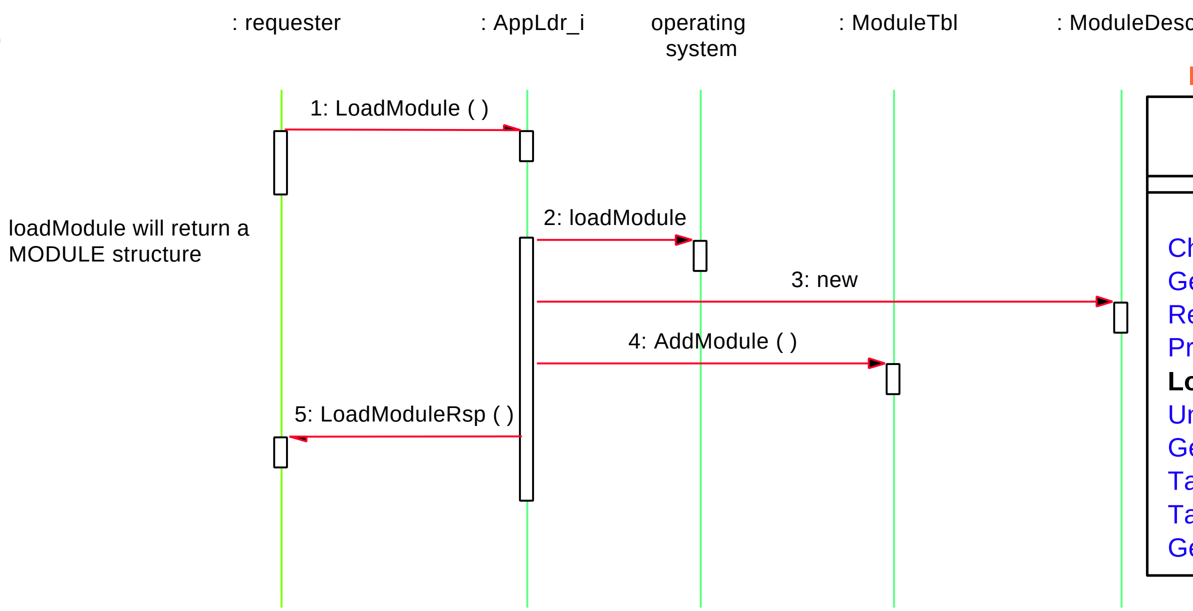
Example: Applications Loader

- **Purpose: Provides the ability to:**
  - **- load and unload software modules**
  - **- facilitates system initialization**
  - **- local CPU task management (start/stop)**
- **responses to commands via IDL interfaces**
- **resides on each PowerPC**
- **controlled locally or remotely**

Architecture Block Diagram



UML Sequence Diagram



IDL (Class Representation)

AppLdr (server)

- SetExecHost( )
- GetBit1DataSize( )
- ReportBIT1Data( )
- ProcssrEcho( )
- **LoadModule( )**
- UnloadModuleByKey( )
- GetNumModules( )
- TaskSpawn( )
- TaskDelete( )
- GetNumTasks( )

IDL (Class Representation)

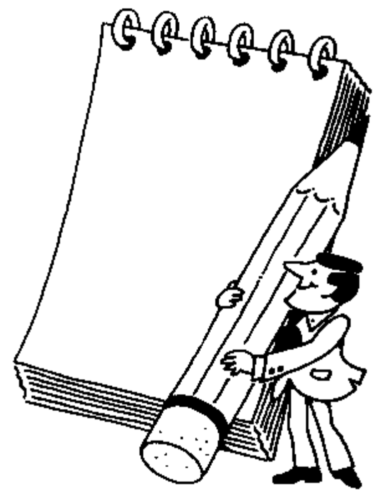
AppLdrR (call Back)

- CheckIn( )
- GetBit1DataSizeRsp( )
- ReportBit1DataRsp( )
- ProcssrEchoRsp( )
- **LoadModuleRsp( )**
- UnloadModuleByKeyRsp( )
- GetNumModulesRsp( )
- TaskSpawnRsp( )
- TaskDeleteRsp( )
- GetNumTasksRsp( )

Sensor System CORBA Usage

CORBA Features Utilized in the Sensor:

- Core ORB (DII, IR, ImR not utilized)
- Static Interfaces
- Lightweight Naming Service (transparent to application)
- mostly asynchronous invocations with calls backs



CORBA Features Desired for Sensor System:

- Naming Service
- Event or Notification Service
- Various forms of asynchronous invocations /w & /wo timeouts
- ORB instrumentation (health, status, & performance via HTTP or SNMP)
- higher fidelity access to and control of the network transport characteristics

Other:

- IDL Style Guide (would have been very helpful)

Lessons Learned

- Training is Highly Recommend for O-O, Language <u>and</u> CORBA
- Concentrate on Architecture/Interface Design (IDL & Hierarchy) - takes time
    - level of abstraction versus granularity - a critical tradeoff
    - careful with chatty client-server interfaces (LAN ® WAN considerations)
- Must Configuration Manage System and Subsystem Interfaces (IDL files)
    - some changes can cause major ripples throughout the system
- Evaluate CORBA Implementations (Prototype, Benchmark, Measure)
    - Verify interoperability
- CORBA can be use for soft/near time embedded applications
    - understand CORBA performance and limitations, then architect system
- Still need to handle application level Quality of Service (QoS)
- Utilize standard CORBA features for <u>interoperability and portability</u>
- Evolve system components along with CORBA standards & implementations
- Not all RT/Embedded Systems needs ALL capabilities of [RT] CORBA
- Architect/Design System around CORBA features available today; try to allow for flexibility to incorporate future CORBA specification enhancements

Concluding Remarks

- CORBA is suited for certain Soft Real-Time Command & Control applications!
- Permits well-defined, interoperable, platform independent system level I/Fs
  - → concentration on application versus low-level mechanics of communication
- Utilize technologies as appropriate; based upon applicability
- **Knowing a CORBA Implementation's operational characteristics (interactions) underneath the IDL interface is very important in embedded and real-time applications**
- CORBA utilized in the CARS C^2 System as well!
- Considered using JAVA [back in 1996, JAVA was not ready for Real-Time or embedded Applications]
- Real-Time/Embedded CORBA Standard(s) will further promote CORBA based real-time/embedded applications

References:

Paper: Masiyowski, J., November 2000, "CORBA & ACE/TAO in SIGINT Systems"; http://www.omg.org → News & Information → Success Stories → Raytheon

Presentation: Masiyowski, J., Iona World 1999, "ORBIX and Object-Oriented Real-Time Distributed Processing System on an ATM Network"