Robotics Showcase

OMG Technical Meeting, Burlingame, CA
Monday, January 31, 2005

The Object Management Group's (OMG's) Robotics Working Group invites you to an Information Day devoted to Computer Standards for Robotics, focusing on the integration of robotics systems based on modular components. Keynoted by i-Robot and anchored by OMG members including the National Institute of Advanced Industrial Science and Technology (AIST) and the New Energy and Industrial Technology Development Organization (NEDO), and supported by JARA (the Japan Robot Association), this day-long program includes presentations on robotics software, the need for standards, and the benefits that the industry can obtain from OMG's open standards for software design and networking. Presentations and technology demonstrations by robotics companies and research institutions in the US and Japan will review the state of the art, industry trends, and viewpoints on standardization. A panel discussion on the future of standardization in robotics will close the day.

Standards speed development and lower costs. The Robotics Working Group invites interested companies to join them in defining a robotics domain architecture and standards suite based on OMG's Model Driven Architecture (MDA; www.omg.org/mda) and Unified Modeling Language (UML; www.omg.org/uml), and taking advantage of the group's other standards for networked real-time, small-footprint/embedded, and high-assurance systems. In addition, these model-based OMG specifications will build upon and integrate interface and message standards from established industry groups, establishing liaison relationships to ensure smooth transfer of technologies between these other organizations and OMG.

Non-OMG members are welcome to attend this meeting; send an email to <info@omg.org> before you register, letting us know that you'd like to come.

To register, click HERE
If you register for the Technical Meeting Week, you do not have to pay the additional fee(s) to attend this special events. If you register only for the Robotics Showcase, the fee is $150.00.

Monday, January 31, 2005 - AGENDA

0900 – 0915	**Welcome** *Dr. Richard Soley, CEO, The Object Management Group*
0915 – 0930	**Robotics Showcase Introduction** *Dr. Kazuo Tanie, IEEE R&A President (AIST)*
0930 – 1030	**Keynote, The Need for Standards in Robotics** *Paolo Pirjanian, Evolution Robotics*
1030 – 1045	**BREAK**
1045 – 1100	**Trends in Robotics and Government's View for Standardization** *Masayoshi Yokomachi, NEDO*
1100 - 1145	**Robotics and NIST** *Hui Min Huang, NIST*
1145 - 1200	**Specialized Standards at OMG: Software Based Communications** *Jeff Smith, Director, Mercury Computer Systems*
1200 – 1300	**LUNCH**
1300 - 1400	**iRobot Demonstration and Case Study** *Todd Pack, iRobot*
1400 – 1445	**mBus Demonstration and Case Study** *Chris Cooper, Software Architect, mBus*
1445 – 1500	**BREAK**
1500– 1545	**Introduction to OMG's MDA and Standardization Process** *Dr. Jon Siegel, VP Technology Transfer,* *Object Management Group*
1600 – 1615	**Future Robotics Group Activity** *Dr.Tetsuo Kotoku, AIST*
1615 – 1700	**PANEL Discussion** *Dr. Makoto Mizukawa, Shibaura Institute*

Introduction to Robot Showcase -why we need RT middleware?-

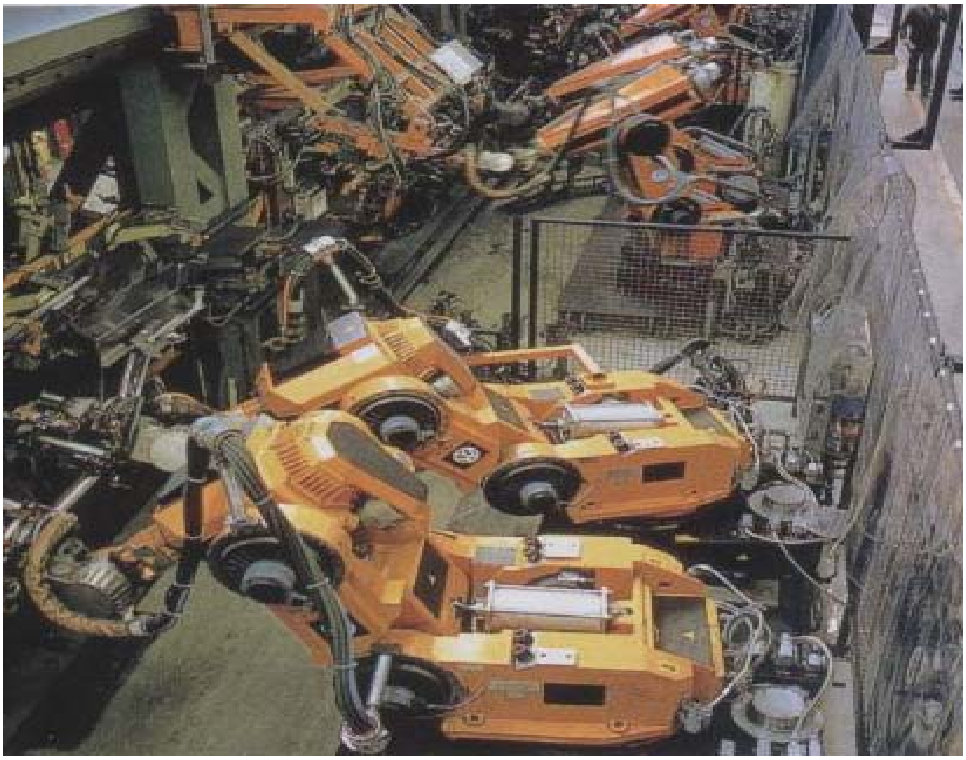
Kazuo Tanie

Principal Reviewer
Evaluation Department, AIST
http://www.aist.go.jp

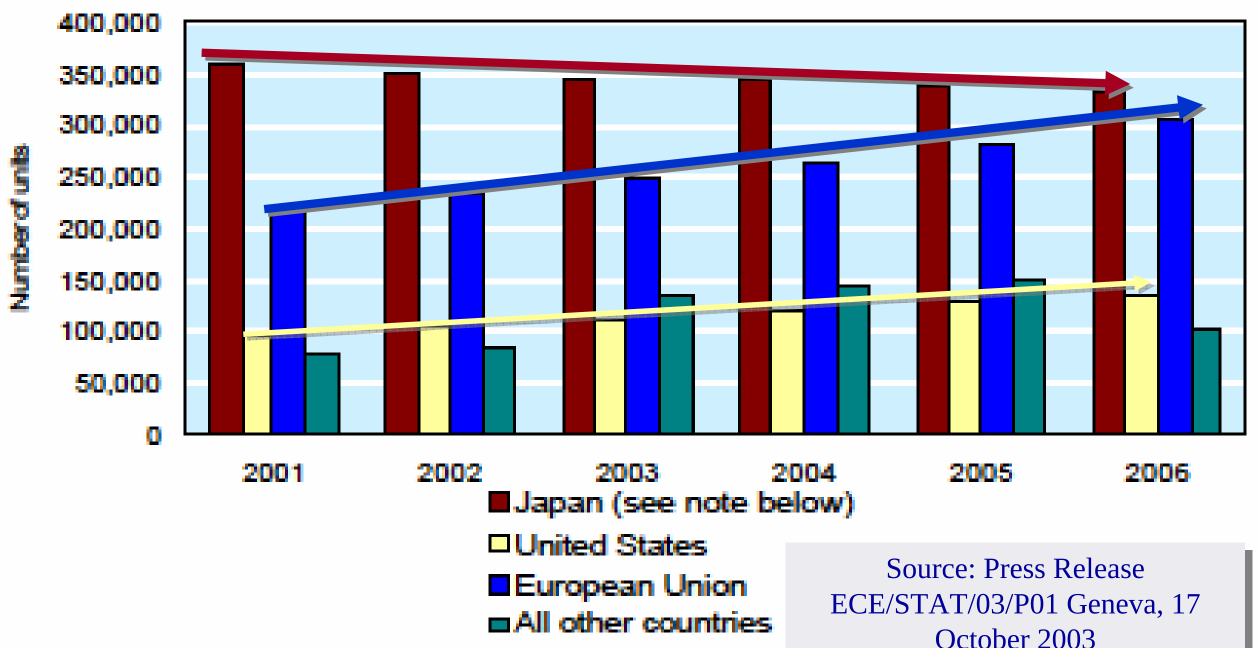
Contents

1. **Robotics Business**
2. **Robotic Design Issue**
3. **Importance of RT middleware**
4. **Future Robotic Business Model**

Industrial Robot



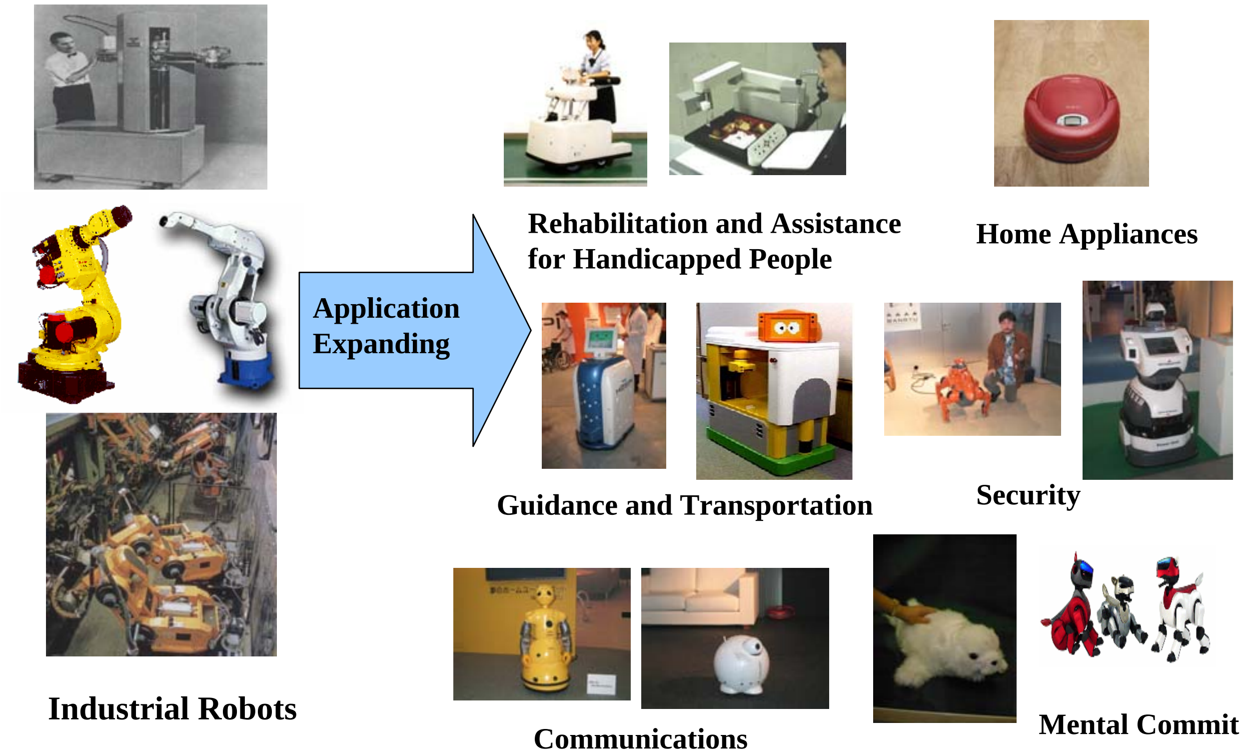
The Number of Industrial Robots used in the World (2003-2006 Predicted Number)



Source: Press Release ECE/STAT/03/P01 Geneva, 17 October 2003

Note 1: Addition to the stock data for Japan included dedicated robots up to and including 2000. Stock data shown here are therefore not fully comparable with those of other countries.

Expanding of Robot Applications
-From Industrial Applications to Non Industrial Applications-



What is the Problems?

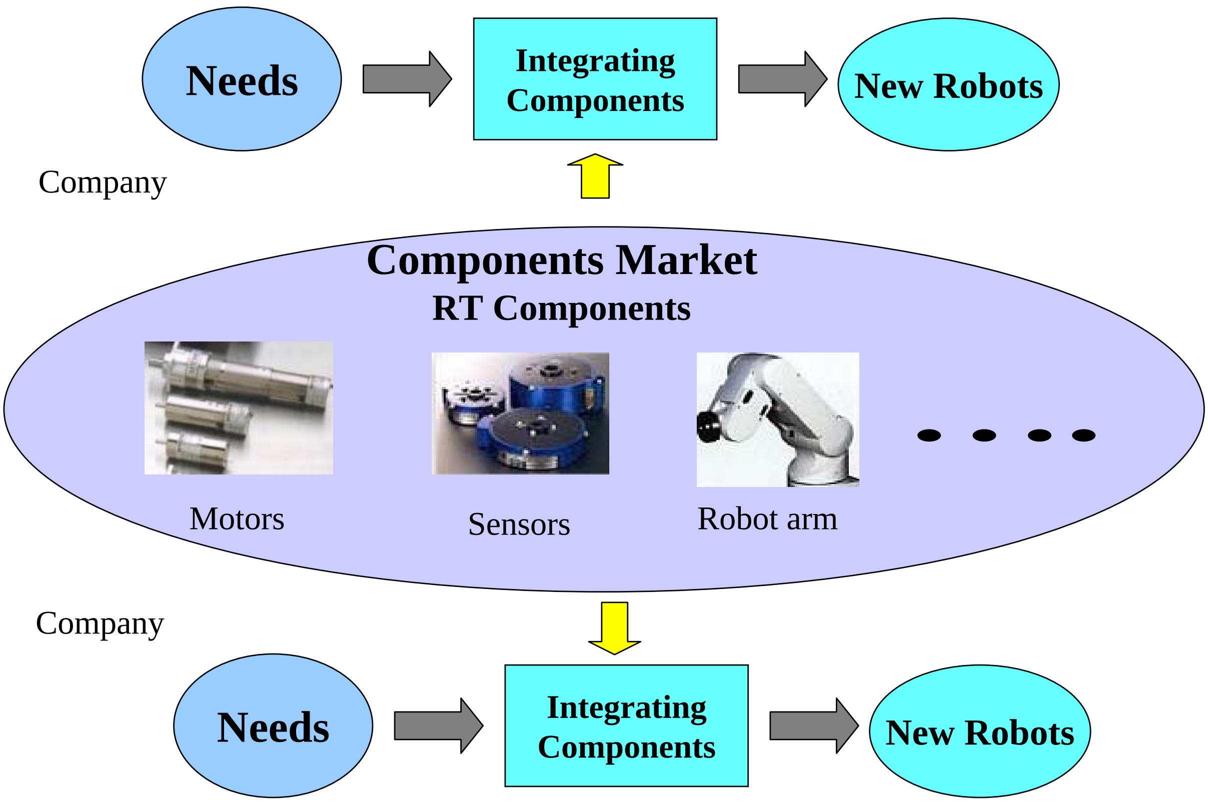
Each user's request is getting personal.

How to provide the good product each user wants to buy?

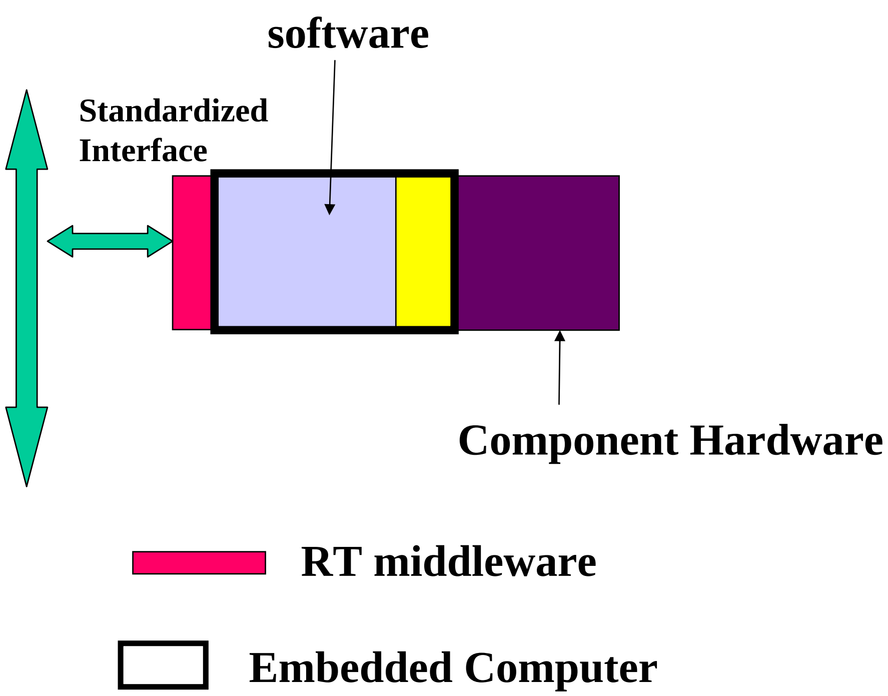
How to design the new products efficiently and quickly?

How to create a new industrial infrastructure which supports the efficient new product design.

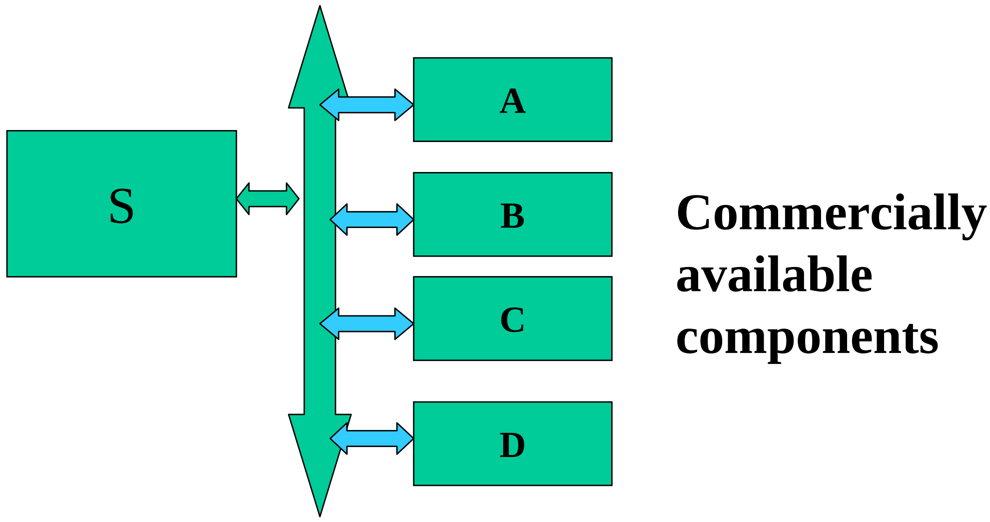
How new robotic products will be produced?



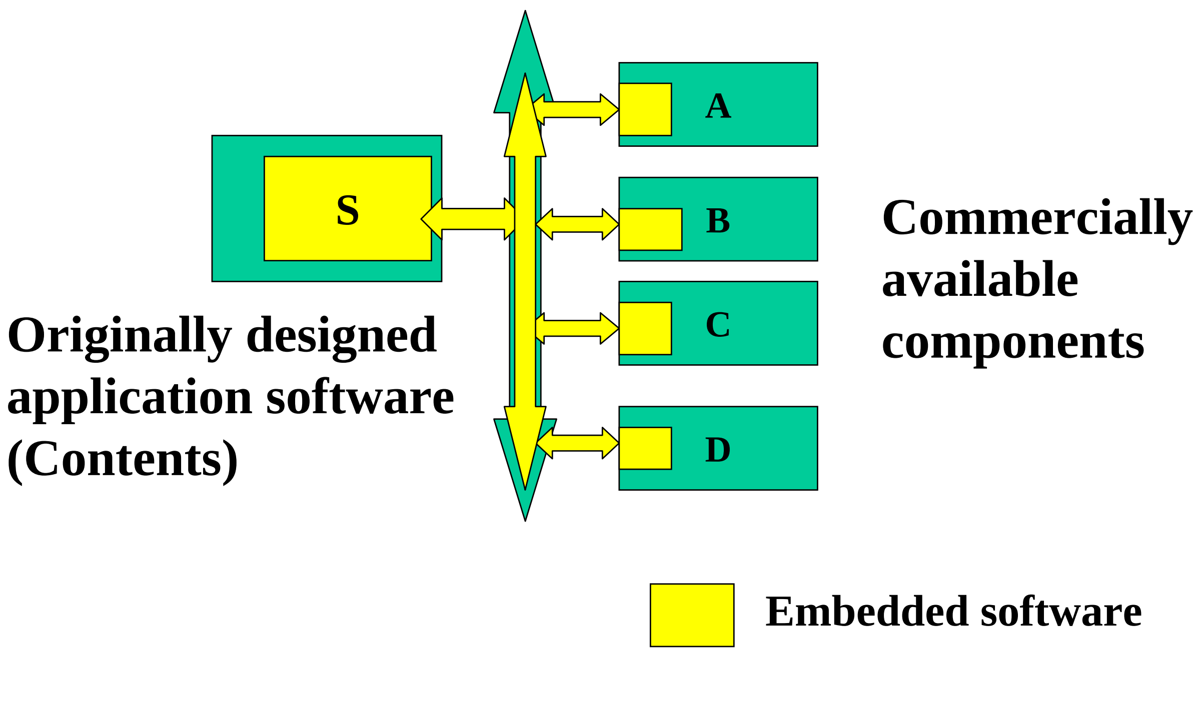
Modularized Component

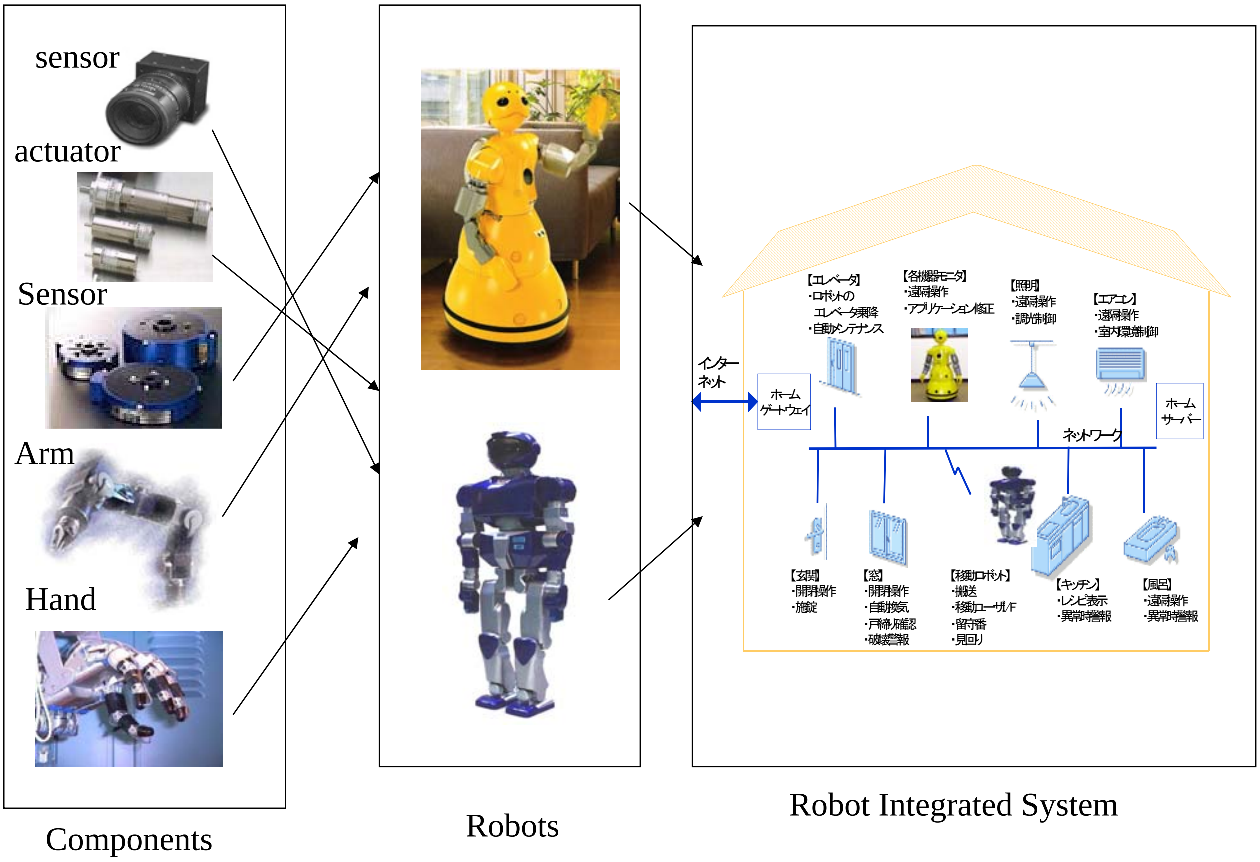


Integrated System



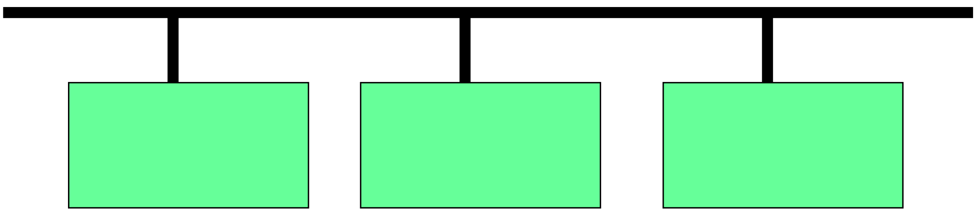
Contents Business



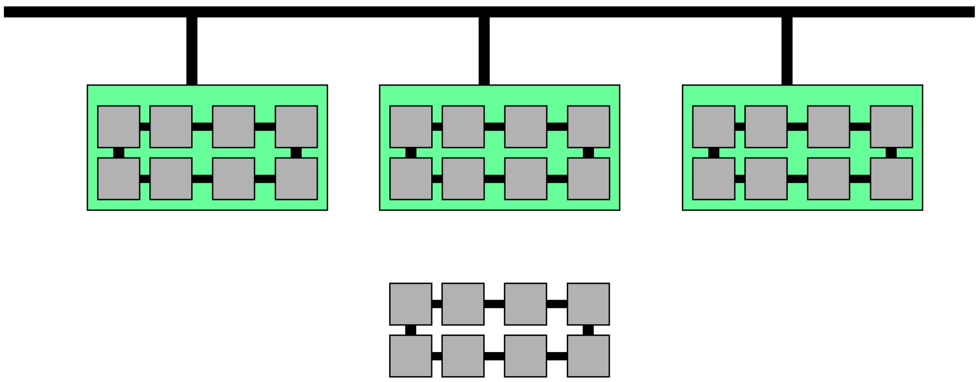


Two kinds of Modularization

Part I　(Subsystem)



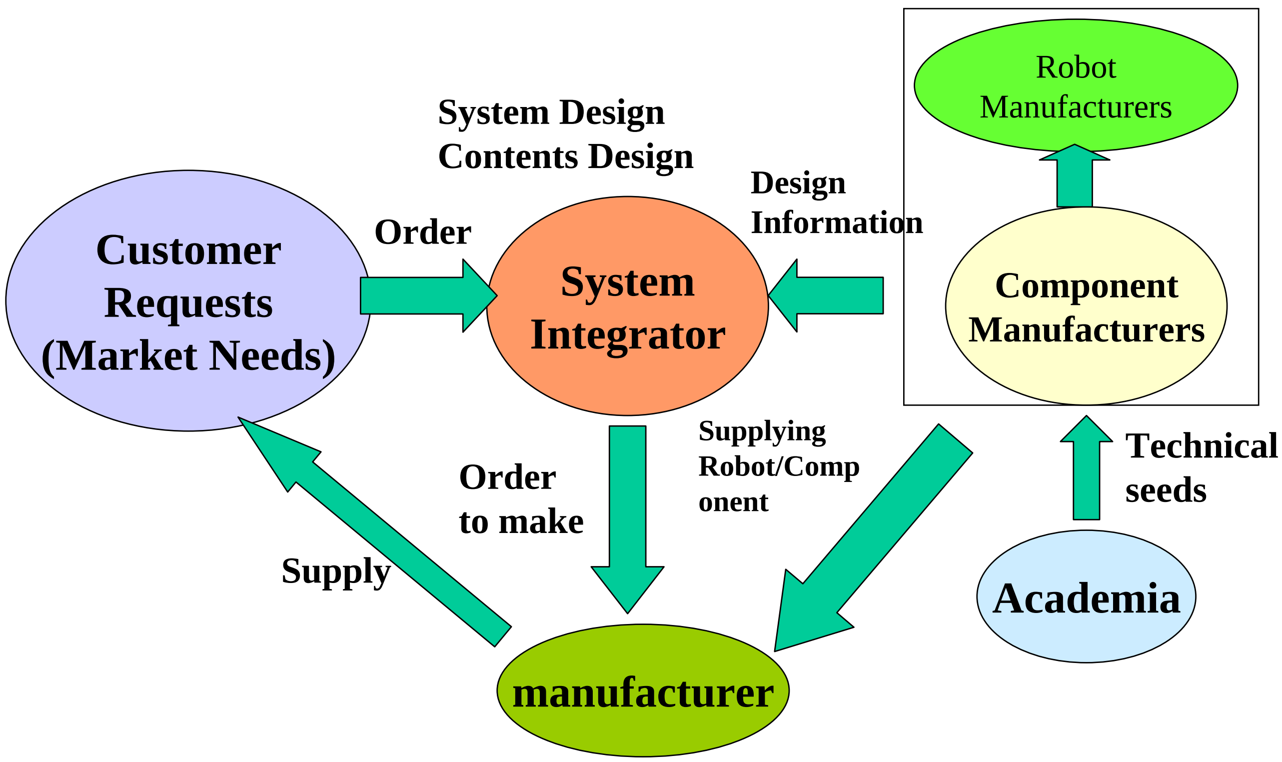
Part II　(Component)



Three Kinds of Robotic Businesses

1. Robot Component Manufacturer
2. Robot Manufacturer
3. Robot System Integrator

A Future Robotic Industry Business Model



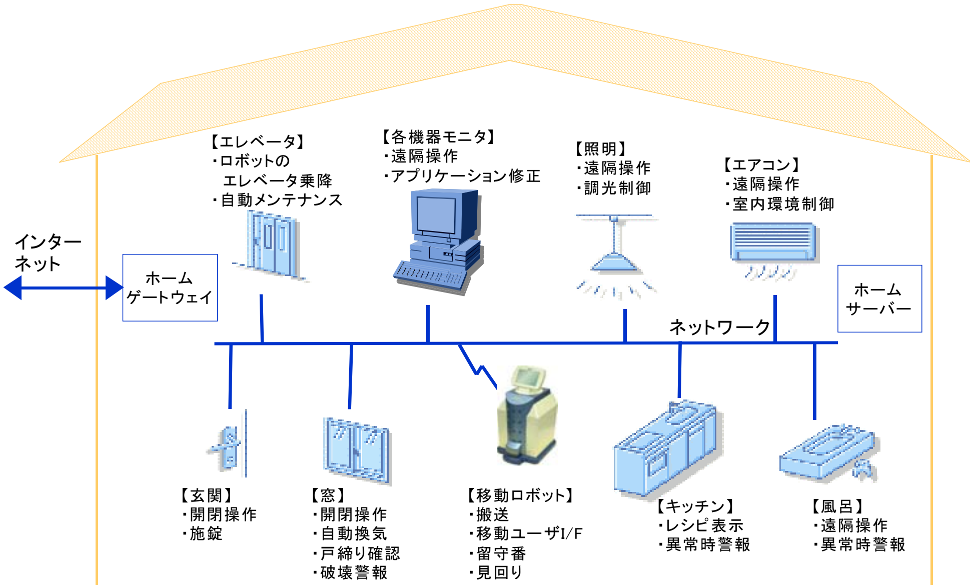


図５　RT要素の統合により設計されるカスタムメイドホームサービスロボットシステムの一例（NEDOミドルウエアプロジェクト）

Thank you

The Need for Standards in Robotics

Paolo Pirjanian, Ph.D.
Chief Scientist and
General Manager for Robotics

Evolution Robotics, Inc.
www.evolution.com

January 31, 2005

robotics/2005-01-03

Overview

- Standards for what?
- What standards?
- Challenges?
- How to build the standards?
- Existing solutions

Problem

- Many apps and robots
- Common functions
- Custom development
- Too expensive and slow

Goal

Faster, Better, and Cheaper

- Reuse
- Leverage
- Evolve

“Simple” robot program

RetrieveFrom(object, destination)

Breakdown (nominal conditions)
- GoTo(destination)
- Recognize(object)
- Grab(object)
- GoTo(home_location)

Contingencies/Issues
- Battery low
- Door closed
- Object not found
- Sensor noise
- Odometry noise
- Unpredictable environment

Break down

GoTo(destination)
- here = Localize(map)
- path = PlanPath(map, here, destination)
- Follow(path)
  - path = (x,y):path
  - MoveTo(x,y)
    - Set_Velocity(motor1, ref1)
    - Set_Velocity(motor2, ref2)
      - write(device_name, ….)
      - ………
  - obstacles = DetectObstacles(sonars)
  - Avoid(obstacles)
  - current_pos = Localize(map)
  - path = PlanPath(map, ….)

Lessons

- Complexity
- Concurrency and coordination
- Contingency handling
- Uncertainty in perception

Porting to another robot

- DetectObstacles(**sonars**)
  - This robot has no sonars
  - This robot's sonars are different
  - This robot's sonars are placed differently

- DetectObstacles (sensors, sensor positions, sensor characteristics, robot shape, ….)

Lessons

- Software complexity
- Concurrency and coordination
- Contingency handling
- Uncertainty in action and perception
- Abstraction of actions/competencies
- What is the correct ‘instruction set’?
- Abstraction of robot, sensors, geometry, mechanics, actuators

What is a standard for robotics?

- Software components
- Hardware components
- Interfaces (hw and sw)
- Interaction rules
- Conventions, anthologies, …
- Structure or Architecture
- ...

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Desired characteristics

- Modularity
- Reusability
- Portability and platform independence
- Scalability
- Lightweight
- Open and flexible
- Ease of integration
- Uncertainty handling
- Fault tolerance
- Testing infrastructure

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Challenges of designing standards

A major task
without clear requirements.

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Challenges of designing standards

A major task
without clear requirements.

- *Many unknowns*
- *Early market*
- *Early technology*
- *Complex technology*
- *Customized for cost*

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Jon’s introduction

- Consensus
- Standardize state-of-the-art

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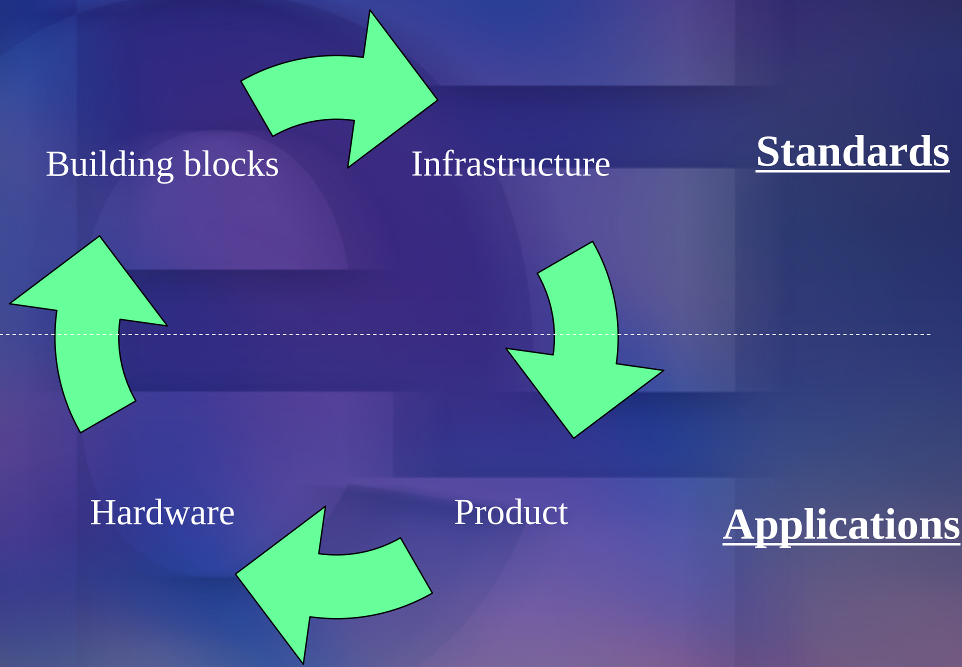
Standards and Applications – Chicken and Egg



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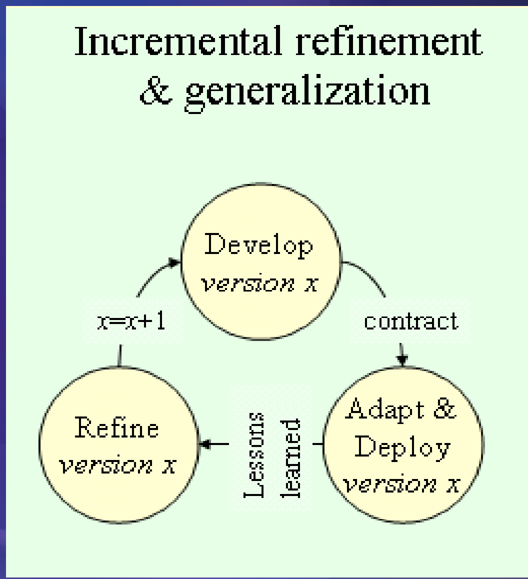
Who develops the standard? How?

- **Design** – Committee/Consortium
- **Implement** – R&D Labs/Companies
- **Deploy** – Product Companies
- **Test** – Consumers

Development philosophy

1. Start with reasonable assumptions about end application and products
2. Set requirements
3. Develop first version
4. Apply to product(s)
5. Learn and refine

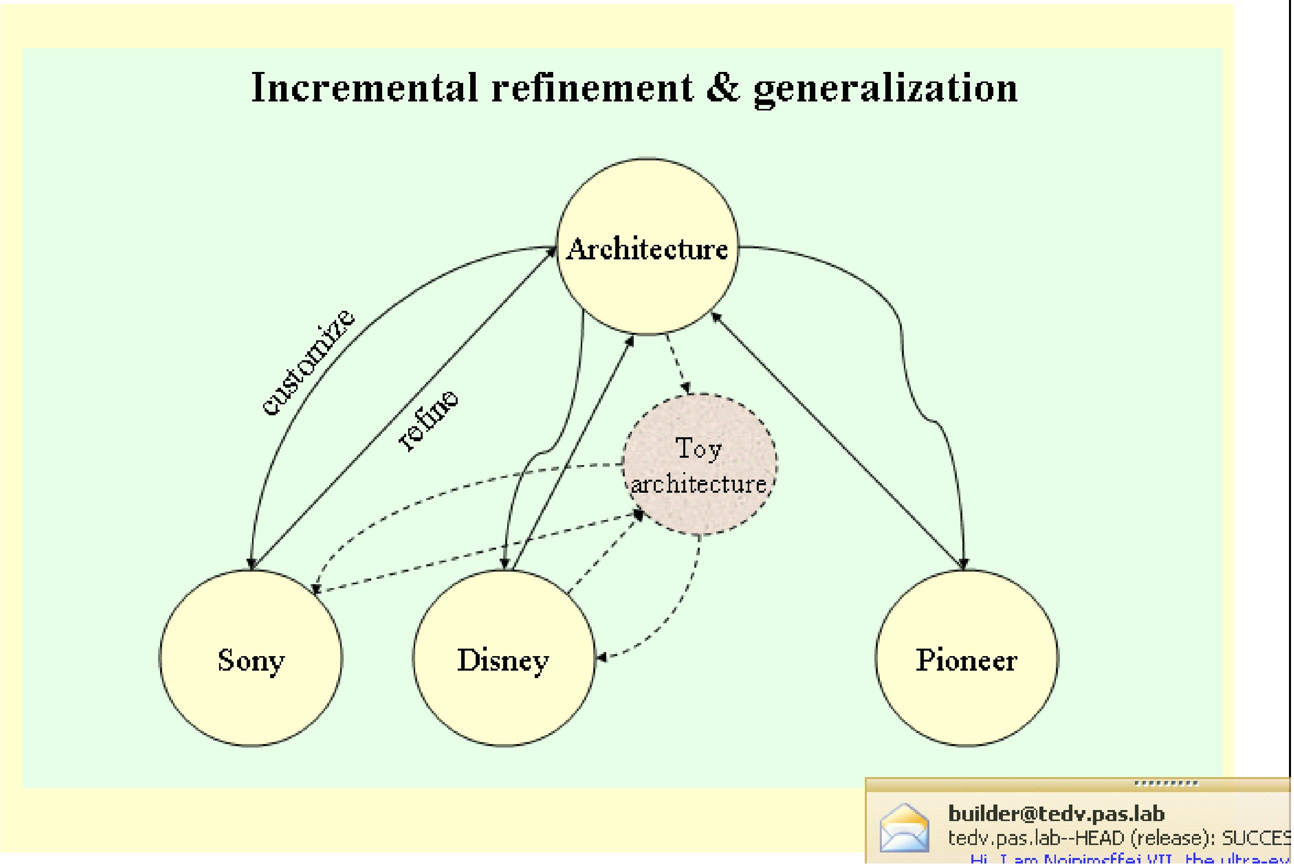


One standard fits all?

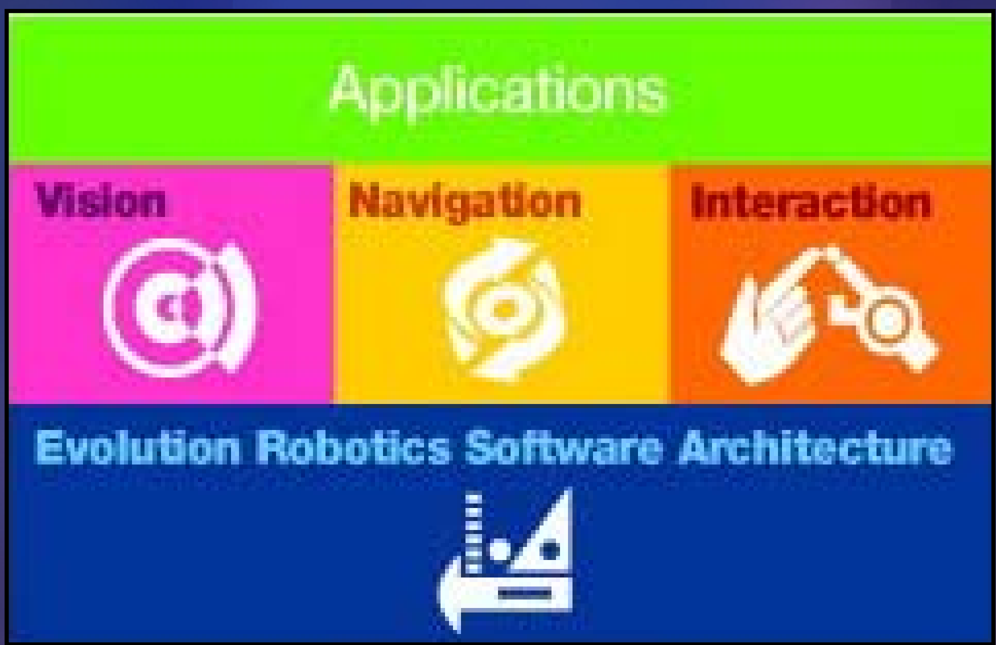
- **Robotic Vacuum**
- 16bit microcontroller
- 16Kbyte RAM
- IR and contact sensors for avoidance
- 2 motor drive
- 1 brush motor
- 1 vacuum motor

- **Entertainment robot**
- Multiple processors, 32-bit CPU, DSP, etc.
- Mega Bytes of RAM
- Cameras, mics, tactile, IRs, ….
- > 16 DOFs

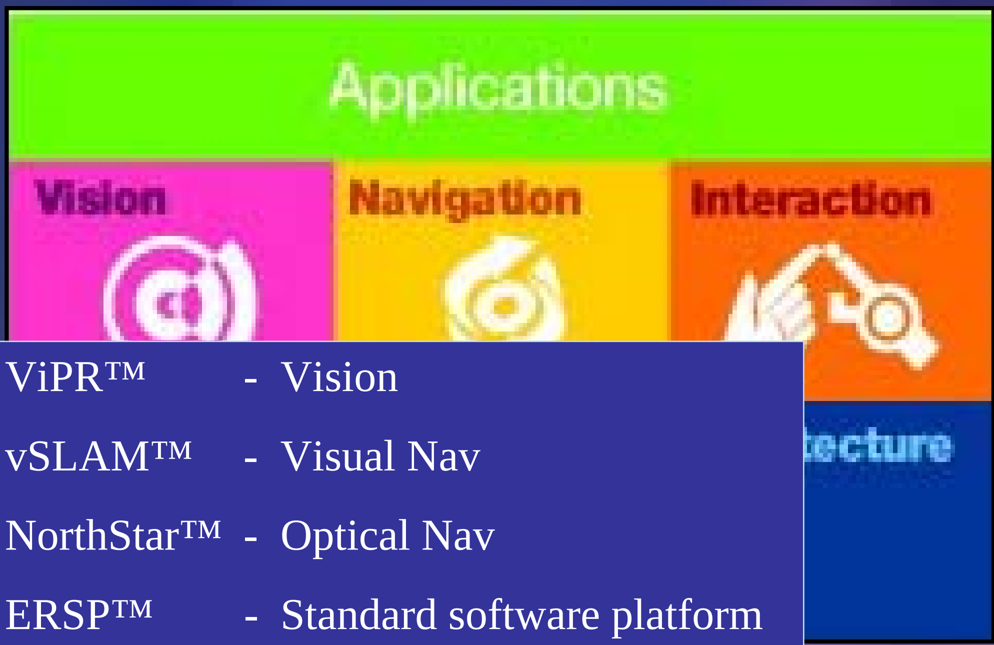
Development Strategy



The building blocks



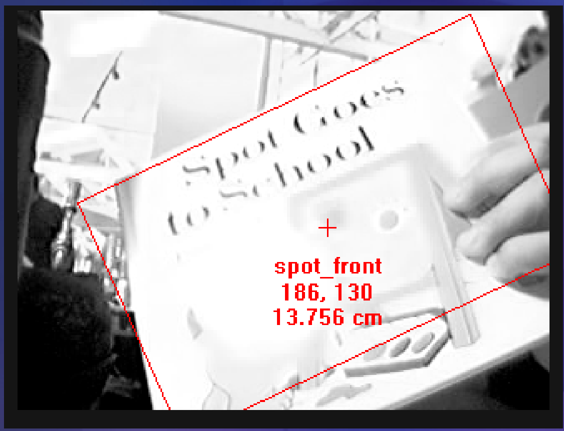
The building blocks



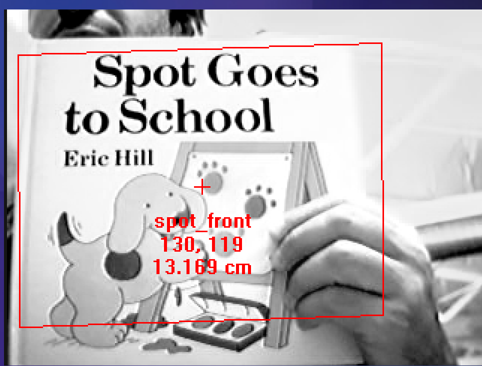
- ViPR™ - Vision
- vSLAM™ - Visual Nav
- NorthStar™ - Optical Nav
- ERSP™ - Standard software platform

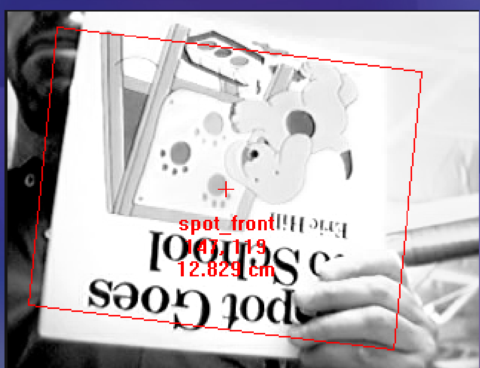
ViPR™: Visual Pattern Recognition

Invariance to changes in lighting

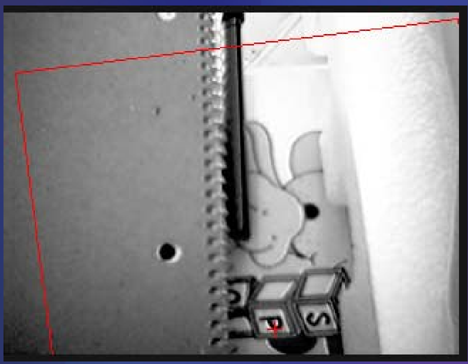


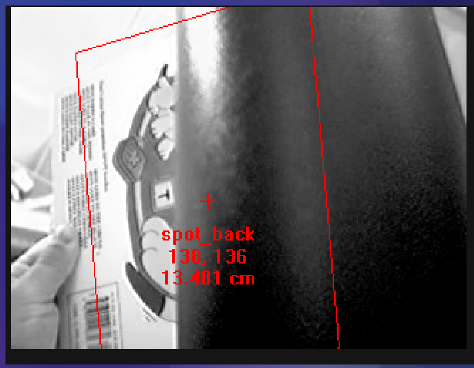
Invariance to rotation and affine transformations

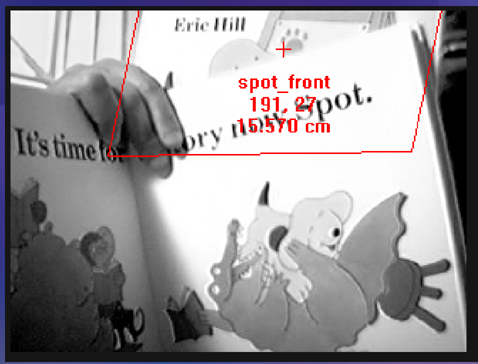




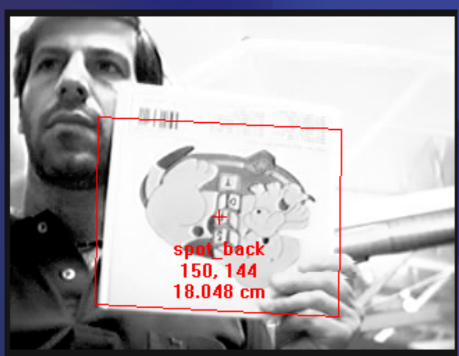
Invariance to occlusions

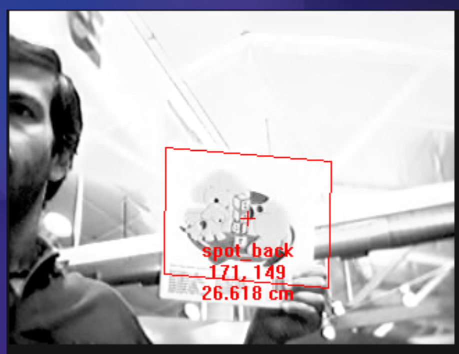






Invariance to changes in scale





Sony AIBO® uses ViPR™

Localization

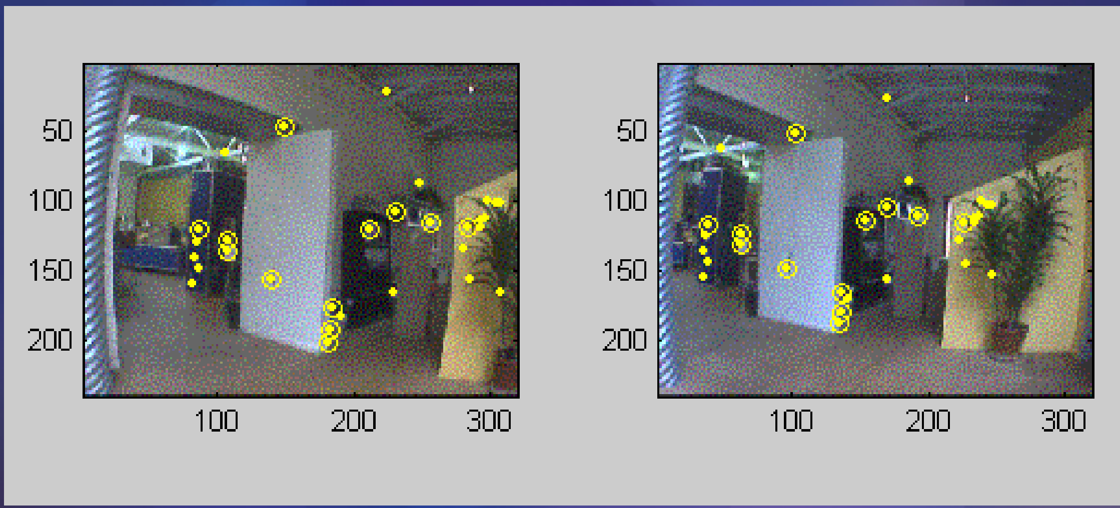
- GPS-capability
- Key for navigation
- Longstanding challenge
- 2 low-cost solutions available

vSLAM™

evolution robotics™

Current Image

Best Database Match (80 cm off)



NorthStar™

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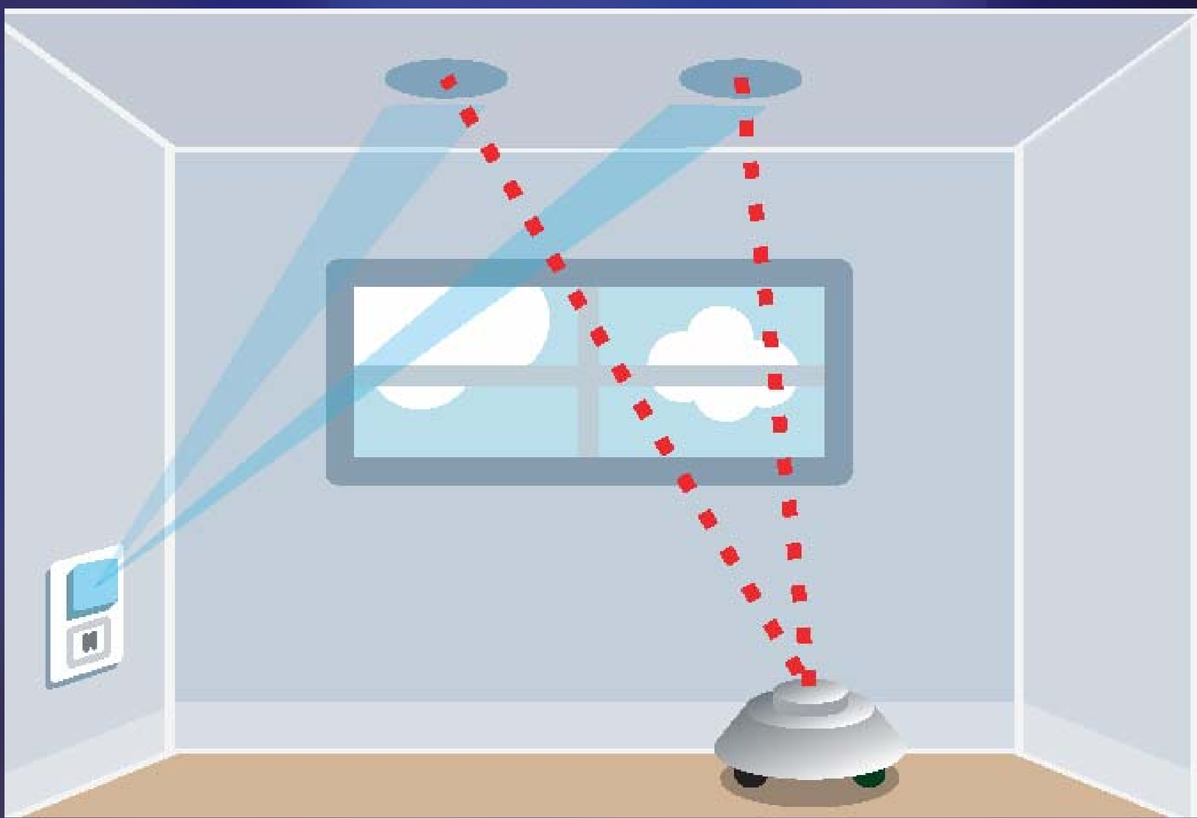
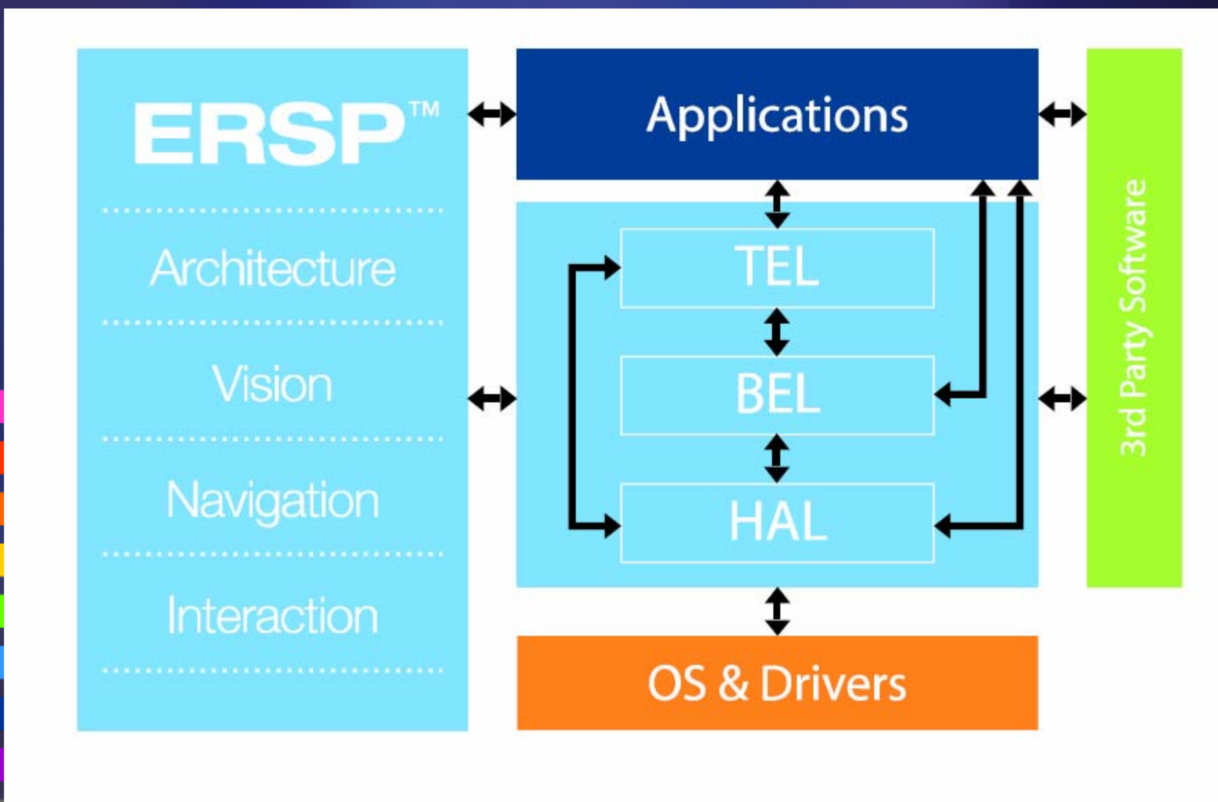


Developer Kits Available

ERSP™



ERSP **Architecture**

Developer Tools
- C++ APIs, XML, Python, GUIs

Applications
- Vacuum, Patrol, Play a game, Read a book

Components
- Object Recognition
  Human-robot Interface
  Navigation, etc.

ERSP Architecture

Task Execution Layer
- Task Manager
- Task Interfaces
- Tasks

Behavior Execution Layer
- Behavior Manager
- Behavior Interfaces
- Behaviors

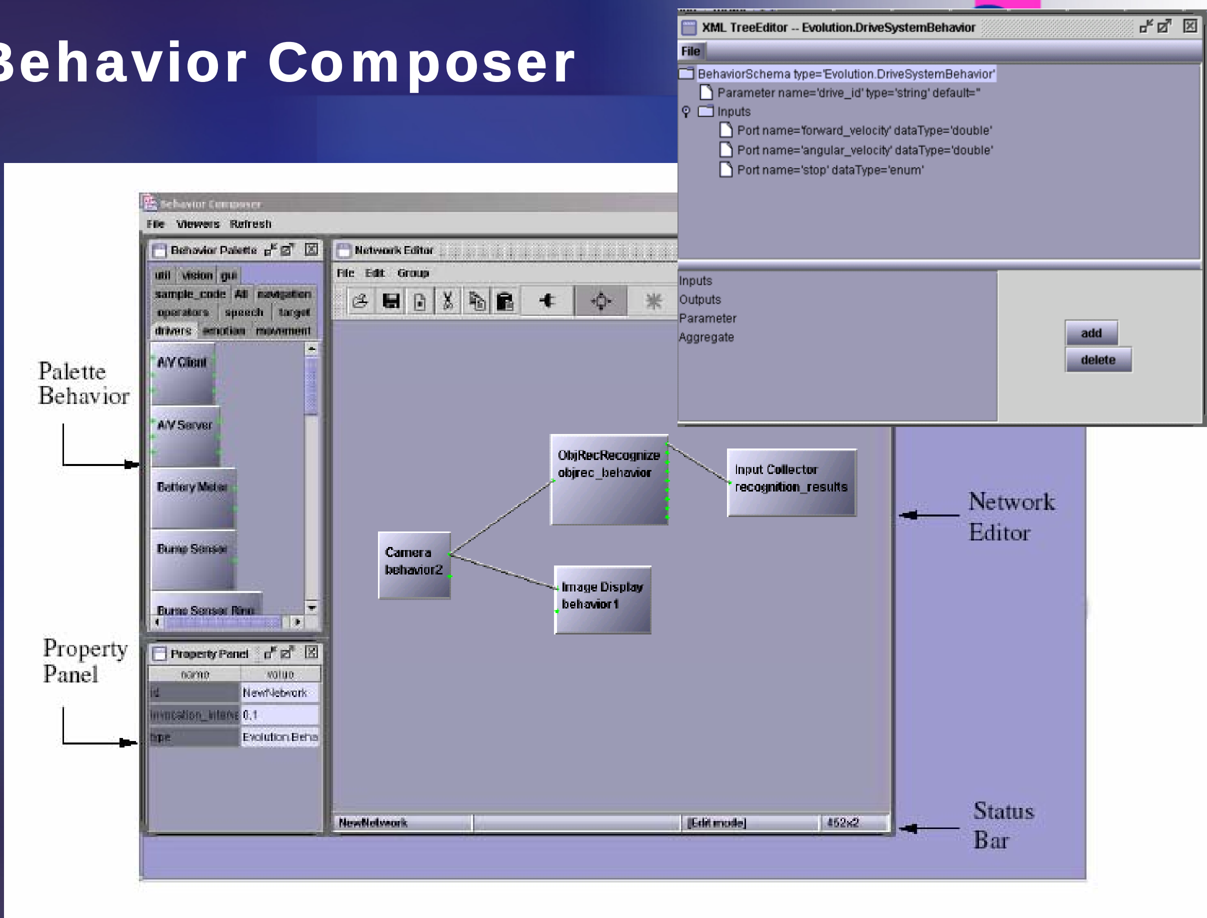
Hardware Abstraction Layer
- Resource Manager
- Resource Interfaces
- Resources

Operating System
- Linux, ITRON, ThreadX
  QNX, RT-Linux, etc.

Hardware
- Sensors & Actuators

Inputs Outputs
- Real-world Stimuli and Actions

Behavior Composer



Camera calibration tools

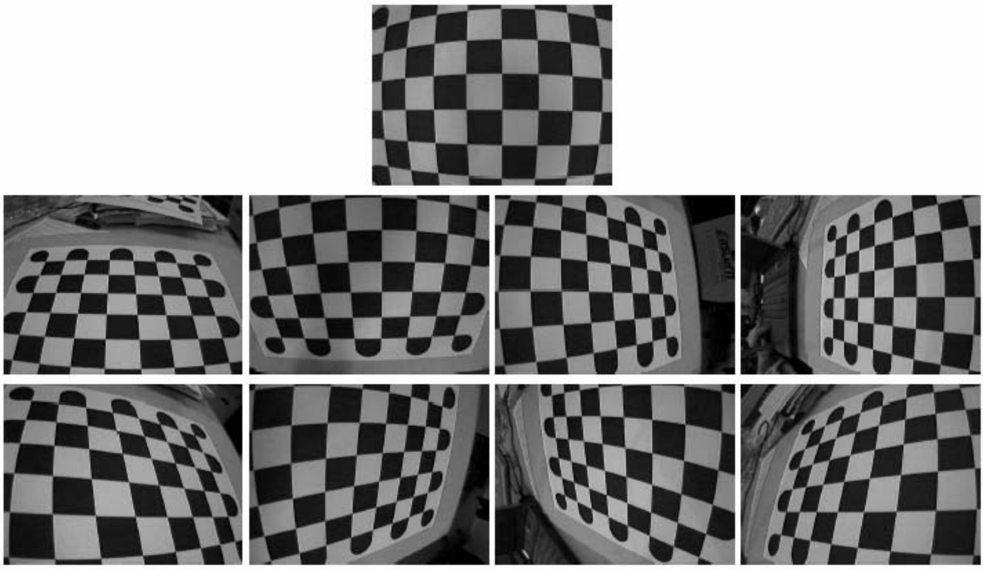
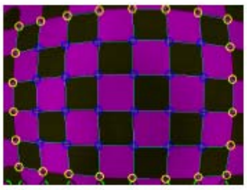


Figure 3.3: A complete set of calibration images.



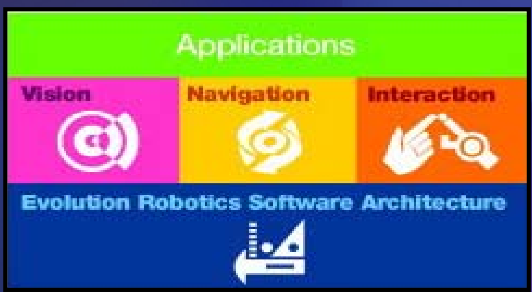
Other tools / modules

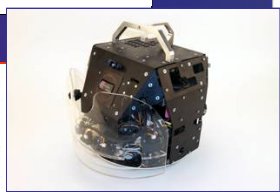
- Computation model of emotions
- Graphical personalities
- Voice recognition and TTS
- Gesture recognition
- Path planning, occupancy grid mapping, obstacle avoidance, ….
- Action selection mechanisms
- Scripting languages Python, XML
- Networked behaviors
- …

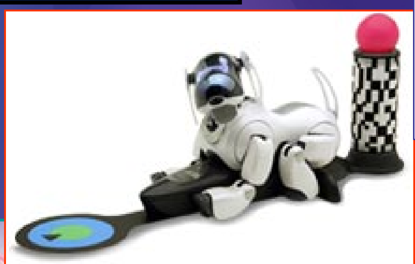
Use Cases

- Modularity/Reusability:
  - ViPR on AIBO
  - vSLAM embedded w/ ViPR on DSP
- Platform independence, portability, etc.:
  - Linux/Windows/Aperios™
  - PMC Sierra, TI DSP, x86, AMD Alchemy, …
  - 40MHz, 8-bit, 32Kb RAM to 2.4GHz P4, 512Mb RAM
- Robot independence, scalability, etc.:
  - Sony AIBO, e-Vac, ER1, Scorpion, ER2, R3R, Pioneers, Simulator,
  - Undisclosed robots from about 30 Corporate Companies and 45 universities

Built on ER Technologies







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Summary

- What is a standard for robotics?
- What are the challenges of robotics?
- Who should develop the standard and how?

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Summary

- To build a standard we need to identify building blocks and interfaces by understanding the target products, hardware, and applications
- We will need more than one software platform for robotics. One per *class* of applications.
- De Facto will determine standard!
  People will use what *they* find useful…

Trends in Robotics and Government's View for Standardization

MASAYOSHI YOKOMACHI
Project Coordinator
Machinery System Technology Development Dept.
NEDO
(New Energy and Industrial Technology Development Organization)

Today's Agenda

1. Introduction of NEDO
2. Trends in Robotics
3. Government's View for Standardization
4. Robot Related Projects In Japan

1. Introduction of NEDO

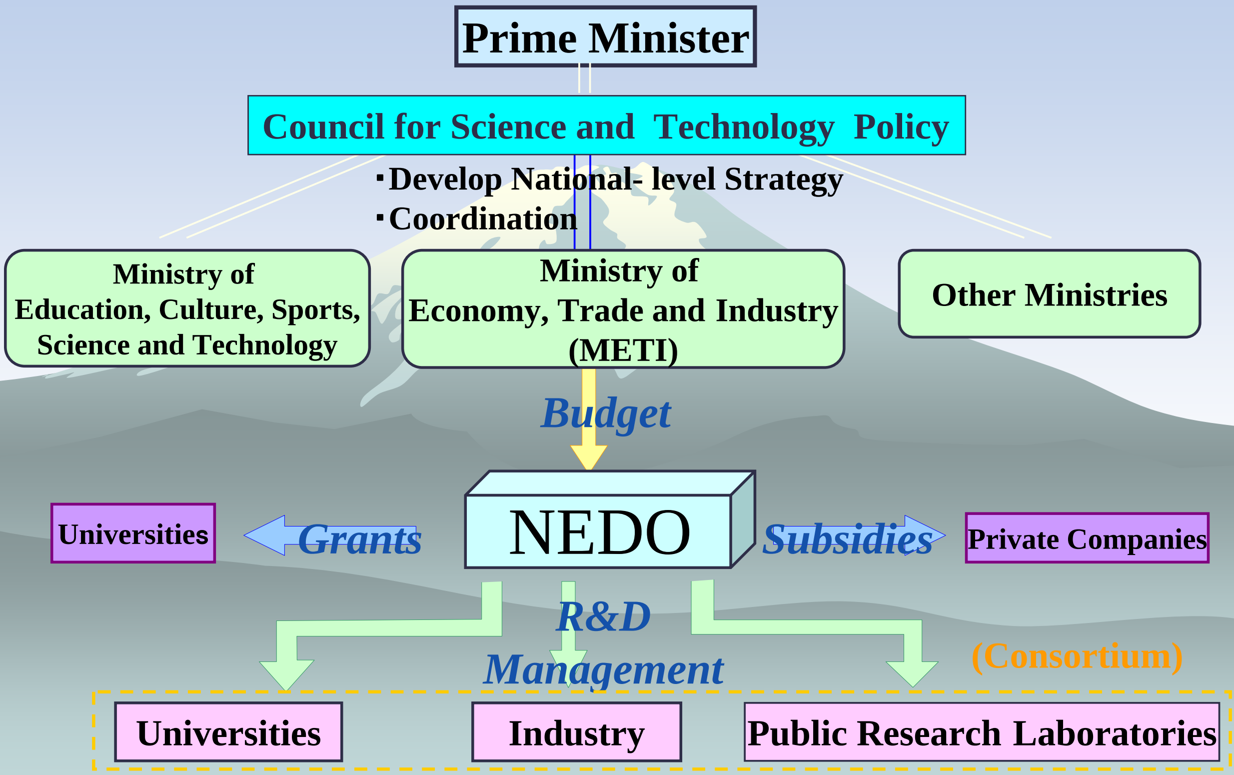
Mission of NEDO

NEDO was established in 1980 and is the largest core organization to promote national level R&D projects in Japan.

- **Promote R&D to Enhance Japan's Industrial Competitiveness**
- **Promote New Energy and Energy Conservation to Strengthen Japan's Energy Security and to address Global Environmental Problems**
- **International Cooperation**

1. Introduction of NEDO

Japan's R&D Promotion Scheme



1. Introduction of NEDO

R&D Expenditures (in FY2003)

（Unit：US$ million）

		FY 2003
★	Electronics / Information Technology	206
	Biotechnology / Medical Technology	182
	Nanotechnology / Materials	146
★	Manufacturing /Aerospace/Avionics/Robotics	241
★	Environment / Energy	585
★	Competitive Grants/Subsidy for Private Companies	267

(Exchange Rate=105Yen/US$) Total 1,627

2. Trends in Robotics

Trends of Market, Technology and Industry

Market Trend

- Market scale of symbiotic Robots in JAPAN ;US$1.5 billion in 2010. (Nakagawa Report;METI 2004 May)
- Near Future,extend its area from welfare/medical,guard,sweeping area to home support area.

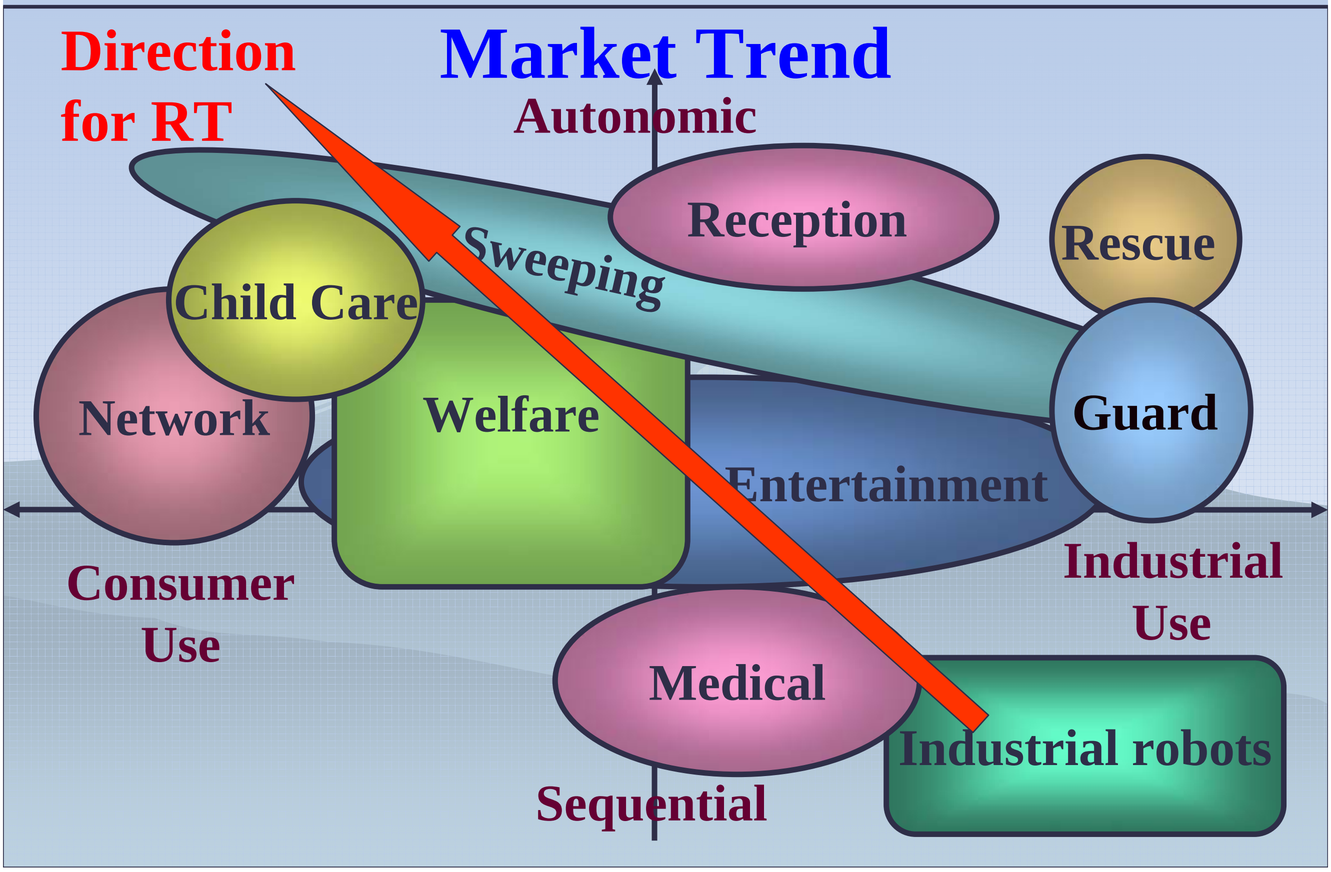
Technology Trend

- Mixed Technology(IT,Mechanical,Nanotech)realizes symbiotic RT.
- The sophisticated IT is most important issue.

Industry Trend

- Open policy stimulates various industries to enter the symbiotic RT Market.
- Main Industries to symbiotic Robots will be IT Venders.

2. Trends in Robotics



2. Trends in Robotics

Technology Trend

Industrial robot → **symbiotic robot**

Industrial robot	symbiotic robot
Sequential control High speed No recess Technical points ・Positioning accuracy ・Handling power ・Multiple axis ・Speed ・Control performance	Intellectual machine Autonomic Recognize human redundancy Technical points ・Autonomic action(learning) ・Speech recognition(conversation) ・Image recognition(biometrics) ・Space recognition(3D) ・Sensors (tactile sense, pressure, acceleration, infrared rays) ・Network protocol

2. Trends in Robotics

Industry Trend

- **Open and module policy**
  - RT middleware standardization
  - New industries enter the market through international standardization activities
- **New industries for symbiotic robots**

Standardization

Industrial robots

Robot makers

Symbiotic robots

IT vendors
Home electronics makers
Parts makers
(mechanical, IC, sensors)
Software vendors
Toy makers

2. Trends in Robotics

Why have symbiotic robots not been realized?

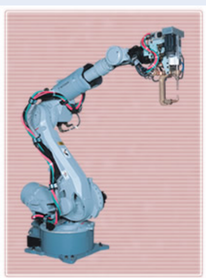
- No common platform.
- Killer applications are not available.

Artificial intelligence

Various killer applications

Space recognition by sensors

Present technology



Common platform

Sequence control

Remote control

Application development

3. Government's View for Standardization

3-1. Headaches

- Robots have been developed and manufactured using an integrated system, so each manufacturer has a different architecture and there is no common platform.

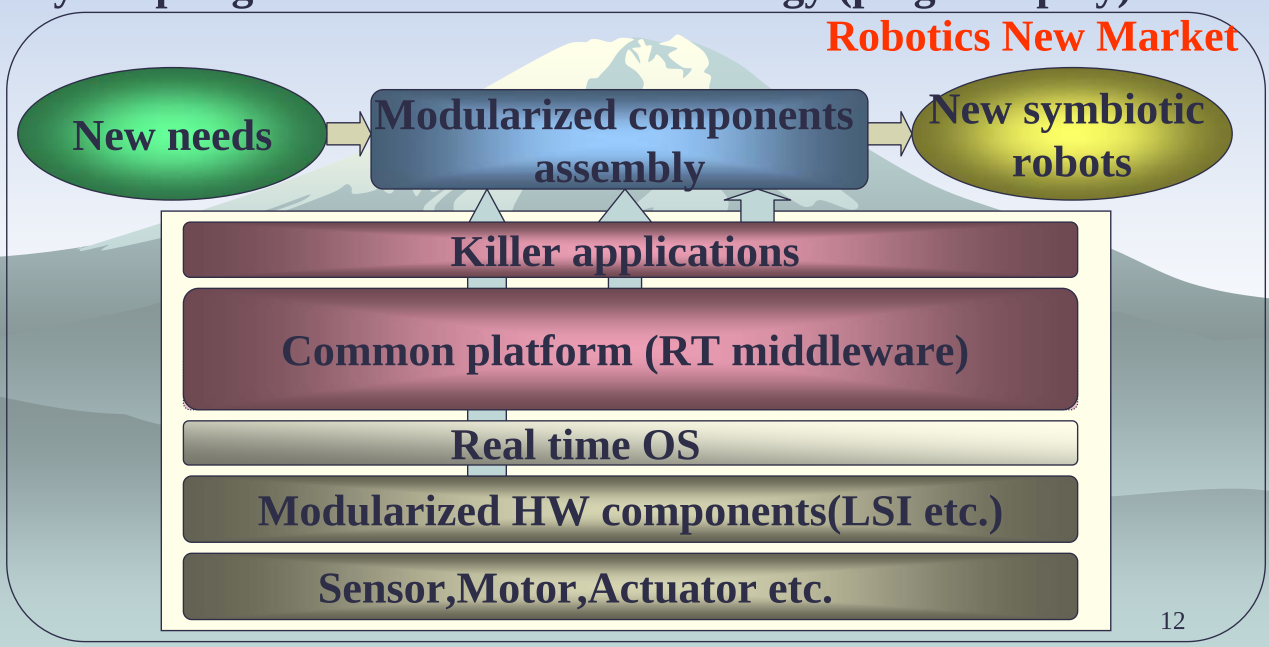
- However, a symbiotic robot needs specific and complex application software, and because of the lack of a common platform, software companies cannot afford the cost to develop so many different software and cannot enter the robot market.

- As a result, companies have no opportunity to attempt any development-related trial and error.

3. Government's View for Standardization

3-2. What should we do?

The assembly-based robot manufacturing should be realized by adapting the modularized methodology (plug-and-play).



3. Government's View for Standardization

3-3. Important Elements

In General,

(1) A common platform is to be established.

(2) A killer application is to be developed.

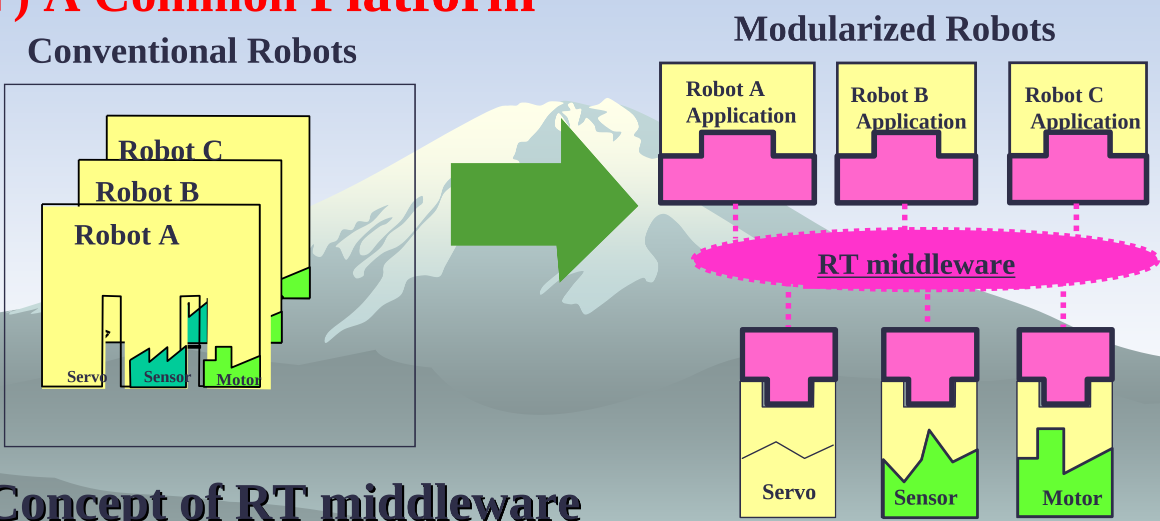
(3) A safe and secure robot is to be realized.

(4) A new market is to be properly created.

3. Government's View for Standardization

3-4. Issues

(1) A Common Platform



Concept of RT middleware

- An Open interface
- Modularized functional components

3. Government's View for Standardization

(2) A killer application

To create a market for symbiotic robots, a killer application is indispensable.

- A killer application should be the one that is used by everyone and is able to provide versatile functionality just like a Web browser.
- A new project to develop symbiotic robots for human welfare and human care is to be started from FY2005.
- A prototype of killer application is to be developed and tried in this project.

4. Robot Related Projects In Japan

The development projects for next generation practical robots
(To be exhibited in International Exposition 2005 in Aichi Japan)

(1)Term : FY2004-FY2005
(2)Budget : abt. US$ 30 million
(3)Objectives :
To develop practical type robots which will be in practical use around 2010, and to develop prototype robots which will be in practical use around 2020.

Next Generation Robot Projects (International Expo. 2005 in Aichi Japan)

Practical Robot

【Reception Robot】
Actroid （Advanced Media Co. Ltd.、Kokoro Co. Ltd. ）

Beautiful lady!!

Practical Robot

【Childcare robot】
PaPeRo （Nihon Electric Co. Ltd.）

Please come to Aichi Exposition and see you!!

Thank you very much!!

Yokomachimsy@nedo.go.jp
(NEDO)

NEDO

ROBOTICS

Research, Measurements, and Standards Infrastructure at National Institute of Standards and Technology

Hui-Min Huang
hui-min.huang @nist.gov

OMG Technical Meeting Robotics Showcase
January 31, 2005

OUTLINE

I. NIST Intelligent Systems Division

II. Approach
- Generic Frameworks

III. Robotics Research, Standards Support, and Performance Metrics
- Unmanned Systems, Industrial Robots

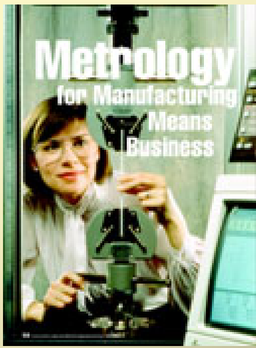
IV. Observations/Position

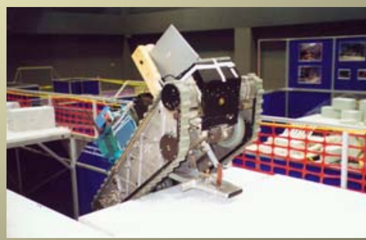
NIST • Manufacturing Engineering Laboratory • Intelligent Systems Division

I. NIST Intelligent Systems Division (ISD)

Mission: To develop measurements and standards infrastructure to enable intelligent systems

- **Unmanned Systems**
- **Homeland Security, USAR**
- **Manufacturing, Others**





http://www.isd.mel.nist.gov

Experience and Customers

30 years of intelligent systems research and measurements & standards development

- DARPA/Army Future Combat Systems
- ARL Demo II, III XUV
- ARL UGV Technology Readiness Level Testing
- DARPA Mobile Autonomous Robot Software
- DARPA LAGR
- TARDEC Taxonomy
- DHS USAR Robot Performance Metrics and Standards
- NIJ EOD Robot Performance Metrics
- DOT Road Departure Warning System Metrics
- DARPA Tactical Mobile Robotics
- DARPA Multiple Autonomous Underwater Vehicles
- DARPA Submarine Automation
- U.S. Bureau of Mines

Experience and Customers (cont'd)

30 years of intelligent systems research and measurements & standards development

- Joint Unmanned System Architecture (JAUS)
- Weapon System Technical Architecture Working Group (WSTAWG)
- ALFUS (NIST)

- Automotive Industry Action Group (AIAG)
- American Welding Society (AWS)
- Open, Modular Architecture Control (OMAC) Users Group

II. APPROACH

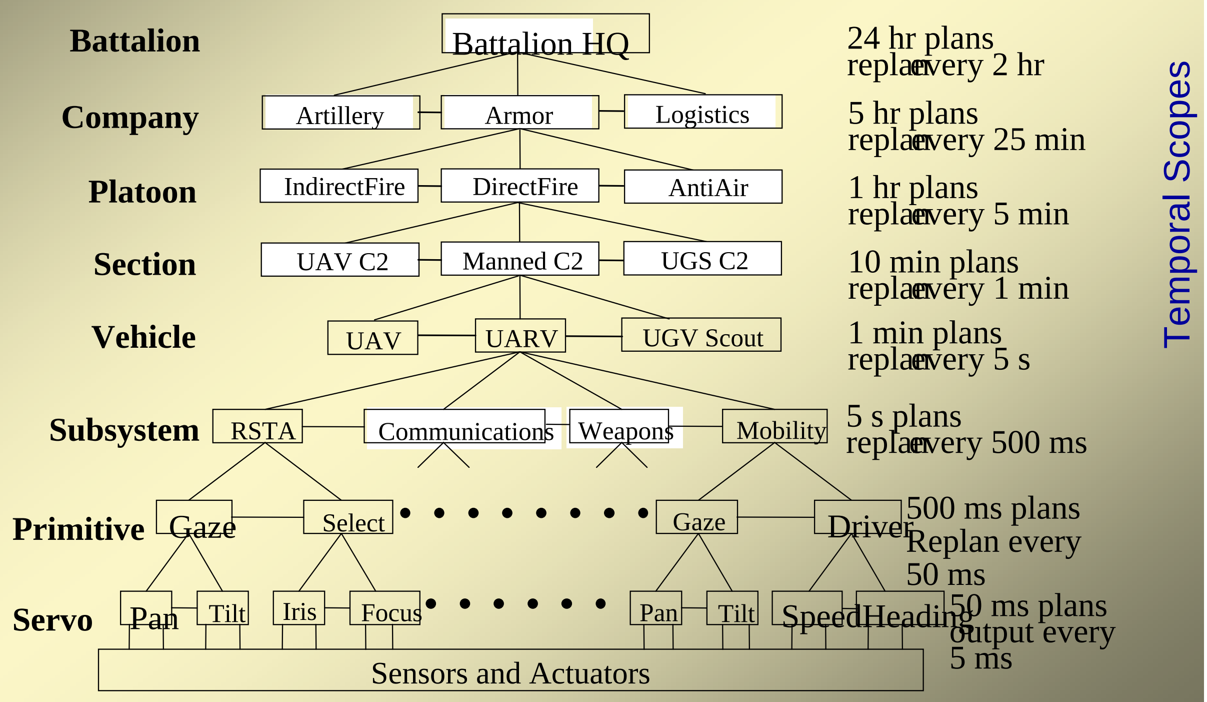
Generic Frameworks:

A. Reference Architecture for Control Systems

B. Performance Metrics

Supporting Metrics, Standards, and Measurement for Intelligent Robotic Systems

4D/RCS REFERENCE MODEL Example



II.A. 4D/RCS REFERENCE ARCHITECTURE

- **Hierarchical, task-based system design & control**
- **Manages complexity through multiple spatial, temporal resolutions**
- **Software engineering benefits**
  - Templates, classes, interfaces, reuse, interoperability
- **Selected as architecture for DOD programs**:
  - Demo III UGV
  - Future Combat Systems Autonomous Navigation System
  - Objective Force Warrior
  - Part of WSCOE, TARDEC VRA

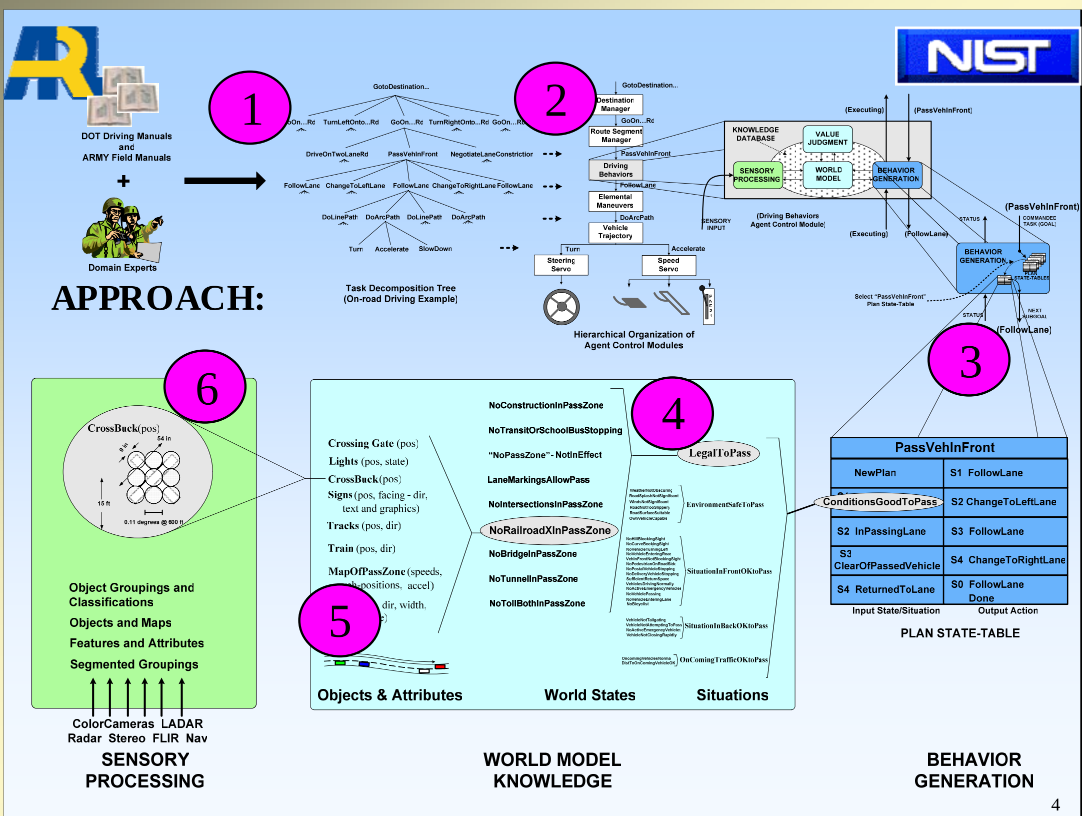
http://www.isd.mel.nist.gov/projects/rcs/

4D/RCS IMPLEMENTAION
REFERENCE MODEL—CONTROLLERS

4D/RCS IMPLEMENTAION REFERENCE MODEL—KNOWLEDGE

Consistent with OMG MDA Concepts

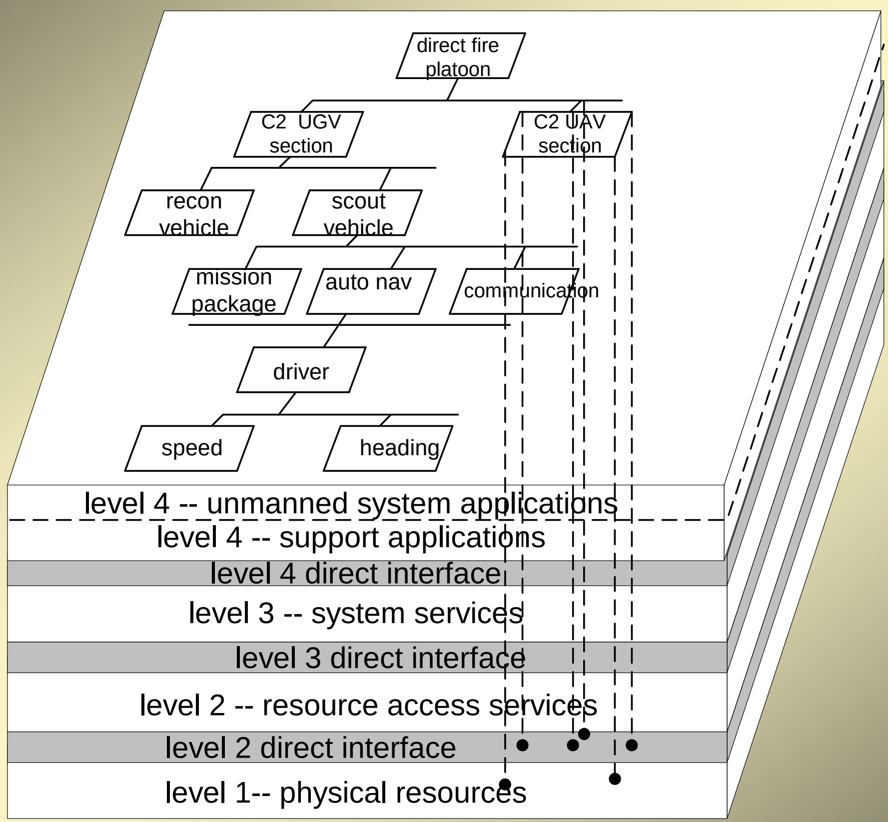
4D/RCS METHODOLOGY



Implementation Example: Demo III XUV

QuickTime™ and a YUV420 codec decompressor are needed to see this picture.

4D/RCS Architecture Facilitating Standards



SAE GOA/ DOD TRM

II.B. Performance Metrics Framework

Autonomy Levels for Unmanned Systems (ALFUS)

↓

Performance Metrics Framework for Unmanned Systems (PerMFUS)

An Ad Hoc Working Group

http://www.isd.mel.nist.gov/projects/autonomy_levels/

ALFUS OBJECTIVE / USER NEEDS

- Standard terms and definitions for characterizing the levels of autonomy *and performance requirements* for unmanned systems.
- Metrics, methods, and processes for measuring autonomy *and performance* of unmanned systems.

ALFUS FRAMEWORK
Clarification

Autonomy vs. Automation

- washing machine vs. scouting mission
- human-less operation vs. human-like performance

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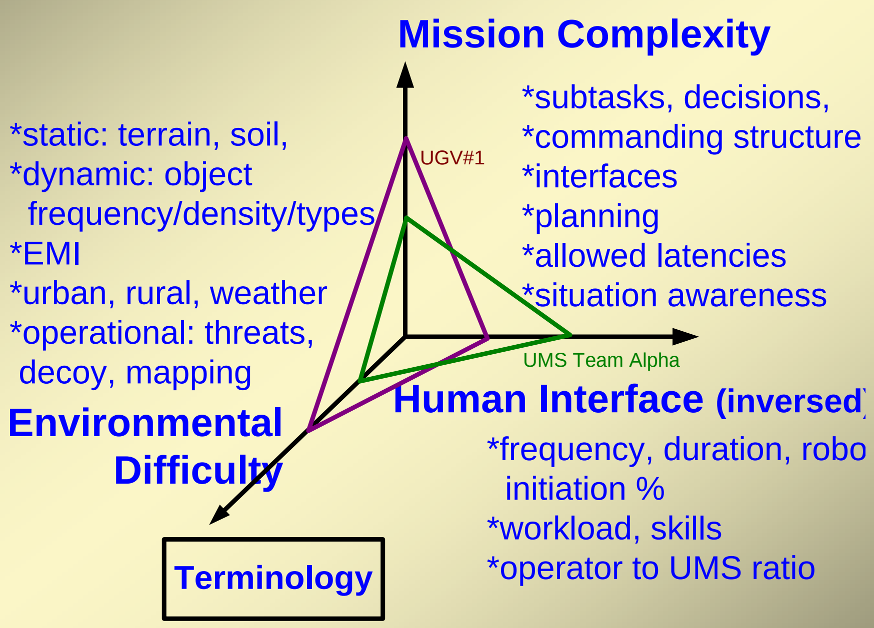
ALFUS DETAILED MODEL



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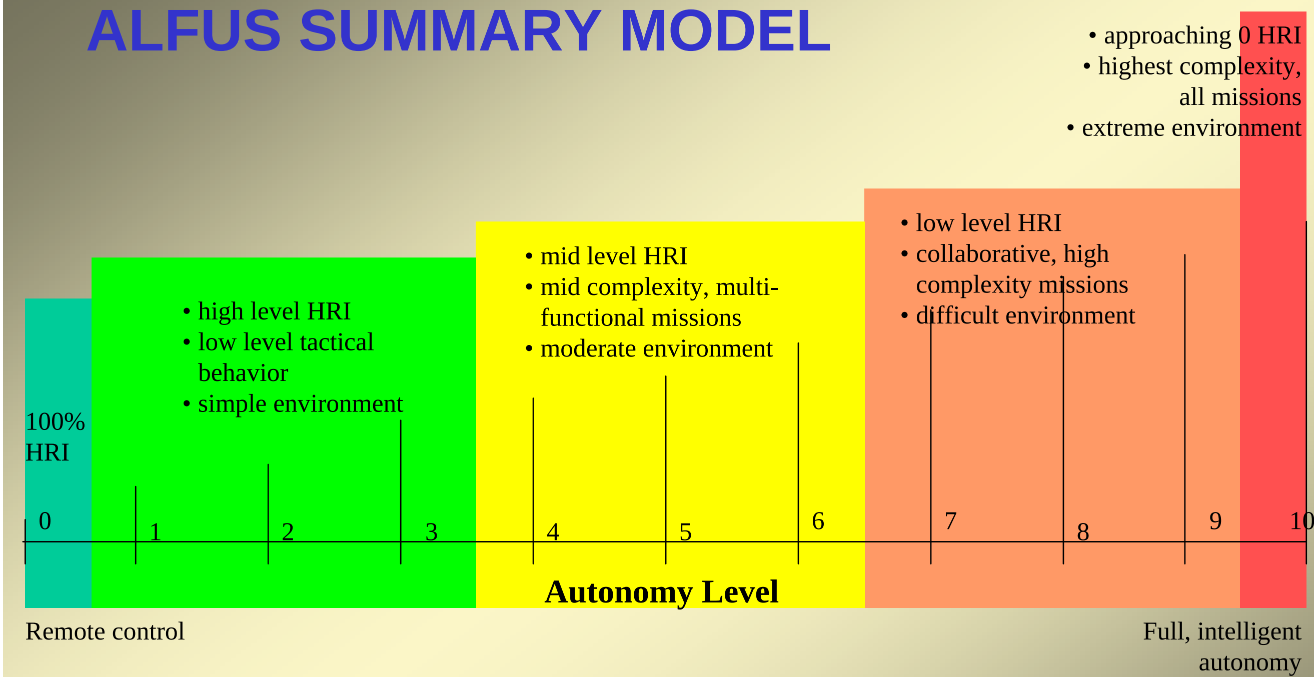
ALFUS TERMINOLOGY

Autonomy Levels for Unmanned Systems (ALFUS) Framework
Volume I: Terminology
Version 1.1

NIST Special Publication 1011

http://www.isd.mel.nist.gov/projects/autonomy_levels/publications/NISTSP_1011_ver_1.1.pdf

ALFUS SUMMARY MODEL



Single actuator/ subfunction → Single function → Single UMS → team

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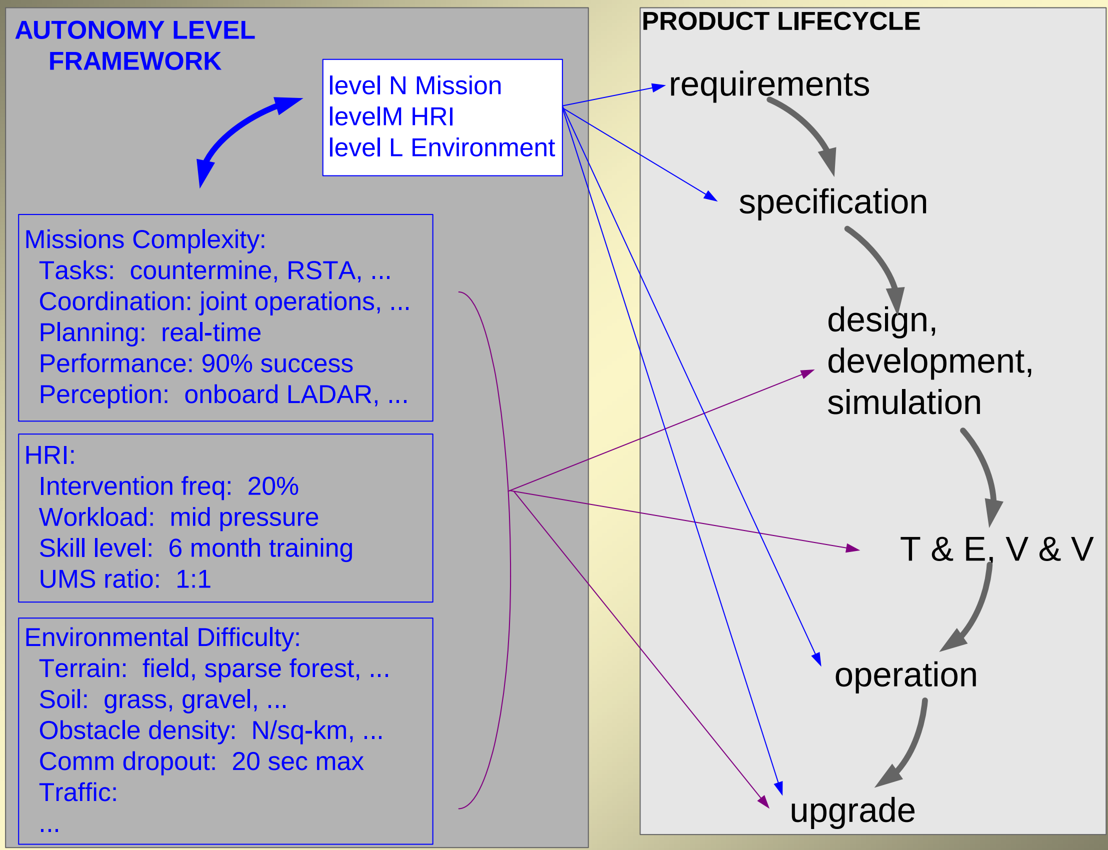


III. ROBOTICS RESEARCH, STANDARDS, AND PERFORMANCE METRICS

A. Unmanned Systems (UMS)
B. Industrial Robots and Other Domains

III.A. UMS RESEARCH, PERFORMANCE METRICS, EVALUATION AND STANDARDS

- Standards Support
- U.S. Army ARL Demo III XUV
- Autonomy Levels for Unmanned Systems (ALFUS)
- Technology Readiness Level 6 Assessment
- DHS Search & Rescue Robot Performance Standard
- Urban Search and Rescue (USAR) Robots
- EOD Robots
- DARPA Multiple Autonomous Robot Software (MARS)
- DOT/ITS Vehicle/Roadway Warning and Control Systems
- Human-Robot Interaction Measures and Standards

STANDARDS SUPPORT

NIST a charter member.

EXAMPLE JAUS MESSAGES

- Code 0008h: Create Service Connection
- Code 0408h: Set Local Vector
- Code 040Ah: Set Travel Speed
- Code 040Ch: Set Global Waypoint
- Code 2402h: Query Global Pose
- Code 4001h: Report Component Authority
- Code 4601h: Report Joint Efforts

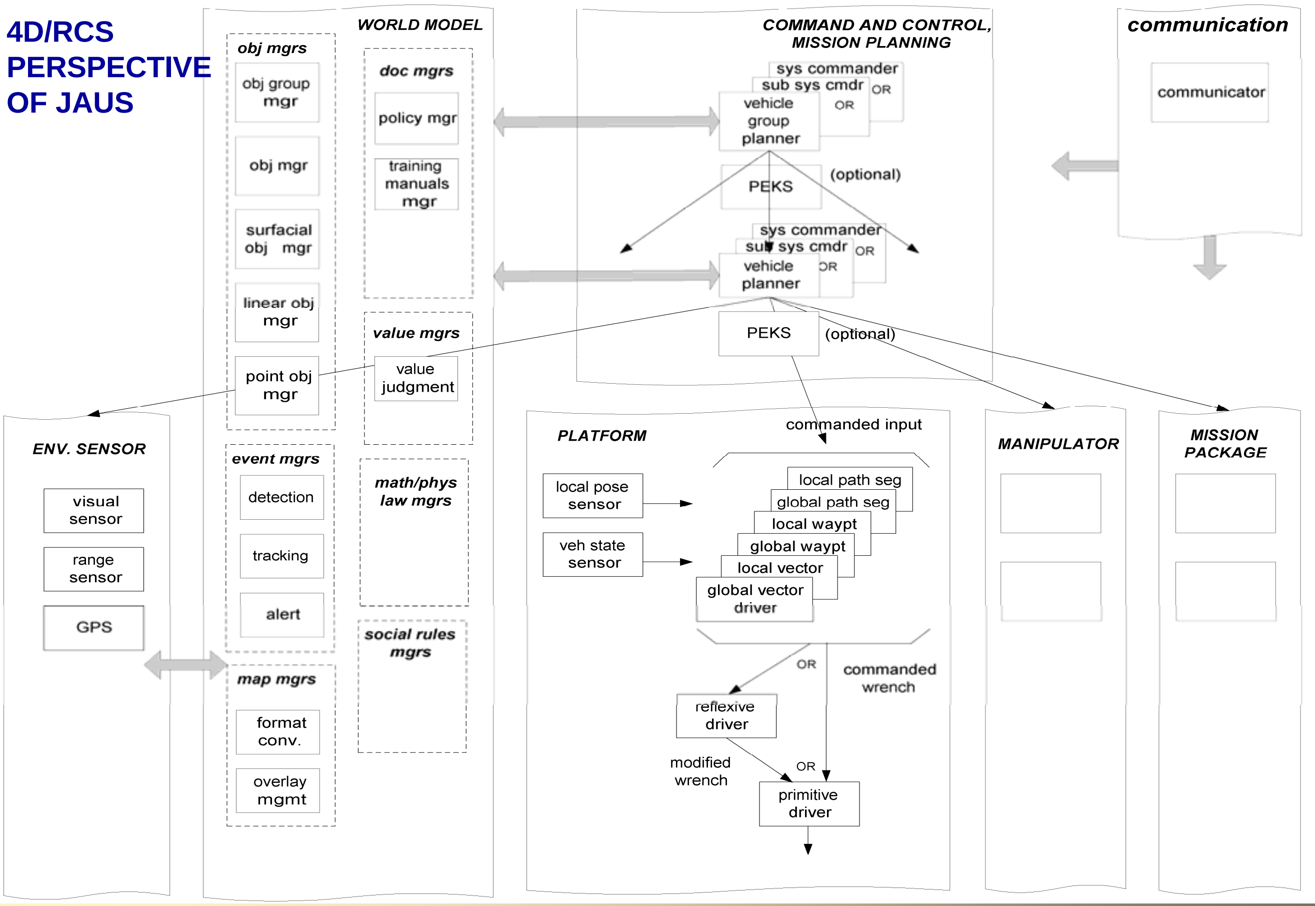
JAUS MAPPING

```
OSI                      TCP/IP                   JAUS
---                      ------                   ----

Application   ---\
                   \
Presentation  -----+-- Application ---------- Application[4,5]
                   /
Session       ---/
                                            /---- Network
                                           /      Environment
Transport     -------- Transport ------+
                                           \
                                            \---- Transport
Network       -------- Network -------------/

                                              /
Datalink      ----\                          /
                   +-- Link -------------/
Physical      ----/
```

Transport: Defines the protocols for the transport of messages between nodes.

JAUS COMPONENT SPACE "BIG PICTURE"

4D/RCS PERSPECTIVE OF JAUS



Performance Metrics and Standards for DHS Urban Search and Rescue Robots

FY04-FY10 NIST-Led National Program

Goal:

Develop comprehensive standards for the development, testing, and certification of effective technologies for sensing, mobility, navigation, planning, integration, operator interaction within search and rescue robot systems . . .

enabling DHS to provide guidance to local/state/federal homeland security entities regarding purchase, deployment, and use of these emerging tools

Performance Metrics and Standards for Explosive Ordnance Disposal Robots

- EOD Specific obstacles and tasks
- Robot/Operator data collection
- Verified performance metrics
- Referenceable artifacts and tests
- Representative practice environment
- Public demonstrations

USAR TEST ARENA PROLIFERATION

FOSTERING COLLABORATION THROUGH STANDARDS

PREVIOUS COMPETITIONS

AAAI Conference 2000
AUSTIN, TEXAS, USA

IJCAI/RoboCup Conference 2001
SEATTLE, WASHINTON, USA

RoboCup 2002
FUKUOKA, JAPAN

AAAI Conference 2002
EDMONTON, ALBERTA, CANADA

RoboCup – US Open 2003
PENNSYLVANIA, USA

RoboCup - Japan Open 2003
NIIGATA, JAPAN

RoboCup 2003
PADUA, ITALY

IJCAI/AAAI Conference 2003
ACAPULCO, MEXICO

YEAR-ROUND ARENAS

NIST
MARYLAND, USA (2000)

Museum of Emerging Science
TOKYO, JAPAN (2002)

Carnegie Mellon University
PENNSYLVANIA, USA (2003)

Istituto Superiore Antincendi
ROME, ITALY (2003)

University of New Orleans
LOUSIANA, USA (2004)

International Univ. of Bremen
BREMEN, GERMANY (2004)

Fire Rescue Training Academy
LISBON, PORTUGAL (2004)

2004 COMPETITIONS

RoboCup - US Open
NEW ORLEANS, USA

RoboCup - German Open
BREMEN, GERMAY

RoboCup - Japan Open
OSAKA, JAPAN

RoboCup 2004
LISBON, PORTUGAL

AAAI Conference
CALIFORNIA, USA

http://robotarenas.nist.gov/competitions.htm

Spectrum Of Test Arenas

Performance Metric For USAR Robots (evolving)

50 POINTS POSSIBLE PER VICTIM FOUND

PENALTIES PER EVENT

$$\text{ARENA WEIGHTING}\left(\frac{\text{MAP QUALITY} + \text{VICTIM LOCATION} + \text{VICTIM TAG} + \text{VICTIM SITUATION} + \text{VICTIM STATE} - \text{ARENA BUMPING} - \text{VICTIM BUMPING}}{\left[1 + \text{NUMBER OF OPERATORS}\right]^2}\right)$$

ENCOURAGES VALIDATION OF LOCALIZATION
(EFFECTIVE ARENA MAPPING)

ARENA WEIGHTING	MAP QUALITY	VICTIM LOCATION	VICTIM TAG	VICTIM SITUATION	VICTIM STATE	ARENA BUMPING	VICTIM BUMPING
1.00/0.75/0.50	10 PTS 5 PTS 1 PTS	10 PTS 5 PTS 1 PTS	+ 10 PTS - 10 PTS	+ 5 PTS	+ 15 PTS - 10 PTS	-20 PTS -5 PTS	-20 PTS -5 PTS

FORM	+/- 1 PTS
MOTION	+/- 1 PTS
HEAT	+/- 3 PTS
SOUND	+/- 2 PTS
CO2	+/- 3 PTS

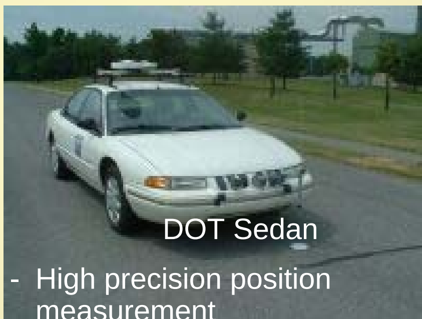
STATE + 5 PTS
(need 3 correctly interpreted)

ENCOURAGES ADVANCED MOBILITY

ENCOURAGES SENSOR FUSION

NIST Mobility Research and Evaluation Test Platforms

HMMWV
- Autonomous operation
- Data collection facilities
- Advanced sensors

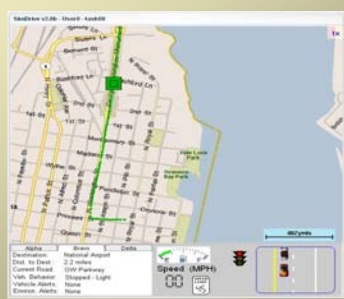


Performance Evaluation and Standards Development Supporting Infrastructure

- Ground truth
  - High resolution sensors
  - High resolution GIS and feature data
- High precision position measurement and tracking
- Test courses, arenas
- Data sets
- Simulation support, combined real-virtual driving
- Capture of operator situational awareness, effectiveness, workload, other measures

Human robot interaction (HRI) at NIST

- Goal: develop standards for HRI, metrics and evaluation methodologies in order to save developmental costs, training costs, and promote more effective use of robots
- Methodology:
  - investigate effective and efficient user interactions in domains of:
    - USAR
    - EOD
    - On-road driving
    - Off-road driving
  - Collect and analyze data at USAR competitions, technical readiness level assessments
  - Develop prototype user interfaces and conduct laboratory studies



HRI Metrics

- USAR
  - Critical incident analysis
  - Time spent in activities
    - Navigation
    - Obstacle extraction
    - Logistics
    - Victim ID
- On &Off-Road driving
  - Time to acquire situation awareness
  - Assessment of situation awareness
- EOD
  - Time to complete tasks
  - Workload
  - User interface workload (clicks, mode changes)

HRI Evaluation Methodologies

- Implementation of Situation Awareness Global Assessment Technique for on-road driving
- Development of standard tasks for EOD with baseline workload, time metrics

III.B. INDUSTRIAL ROBOTS AND OTHER DOMAINS

1. Standards:
   - American National Standards Institute (ANSI)
   - Robotic Industries Association (RIA)
   - Open DeviceNet Vendor Association (ODVA)
   - Medical Robots

EtherNet/IP ODVA

RIA—Robot Communication Interface

Recommend an industry roadmap in robot communication standards that will benefit robot end users by providing a standard method for interfacing to the robot controller

EtherNet/IP Device Standards & Performance

- ODVA Maintained and NIST participated multiple standards
  - DeviceNet
  - EtherNet/IP
  - CIP Safety
  - CIP Sync
- Develop performance metrics & tests for EtherNet/IP devices to allow users to compare products from multiple vendors using a common set of terms and values

ADDITIONAL ISD PARTICIPATION

- ANSI/RIA R15.04 Factory Data Network Interface for robots
- "American National Standard for Industrial Robots and Robot Systems - Point-to-Point and Static Performance Characteristics -Evaluation," ANSI/RIA R15.05-1-1990.
- "American National Standard for Industrial Robots and Robot Systems - Reliability Acceptance Testing - Guidlines," BSR/RIA R15.05-3-1992.
- "American National Standard for Industrial Robots and Robot Systems - Path-Related and Dynamic Performance Characteristics -Evaluation," ANSI/RIA R15.05-2-1992.
- "American National Standard for Industrial Robots and Robot Systems- Safety Requirements," ANSI/RIA R15.06-1999.

Ongoing:

- R15.06 Technical Report for the teaching of multiple robots in a common safeguarded space.
- DRAFT INTERNATIONAL STANDARD ISO/DIS 10218Robots for industrial environments -- Safety requirements
- Performance testing of orthopaedic surgical robots.

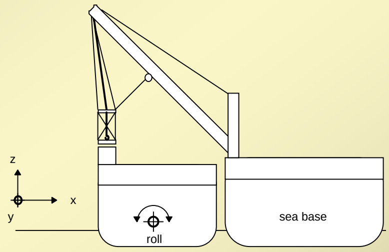
III.B. INDUSTRIAL ROBOTS AND OTHER DOMAINS

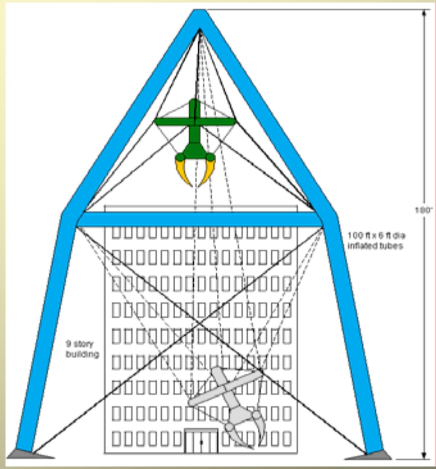
2. Robotic Research
   - **RoboCranes**
   - **Industrial Mobile Robots**
   - **Nano manipulation**
   - AMRF
   - DARPA MAUV, Submarine Automation
   - Coal Mining Automation

Rapidly-deployed Intelligent RoboCranes™

large scale, heavy-duty, low technical risk

- Ship-board Container-handling Cranes
  - Skin-to-skin Replenishment Project for ONR, joint project with industry
  - generic design to access most any ship
  - full 6 DOF control of dual spreaders for container access of top-deck stacked containers and containers within any cell
- Rapidly-deployed Inflatable Structures that support RoboCrane
  - with lifting and cutting tools for dexterous removal of heavy (> 5 tons) rubble from collapsed buildings.
  - access to large buildings and structures without touching
- http://isd.mel.nist.gov/projects/robocrane

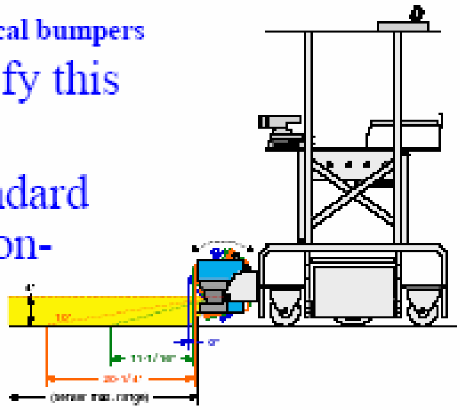




INDUSTRIAL MOBILE ROBOTS

Advancing Standards: ASME B56.5
Automated Guided Vehicle Bumpers

- ASME B56.5a-1994 is confusing to AGV vendors and users ...do AGV's require a contact bumper?
  - "Mandatory emergency control functions and devices shall include ... sensing device or combination of devices to prevent contact of the object sensed with the vehicle structure in the direction of travel."
  - **Yet, specifically defines mechanical bumpers**
- NIST is working to clarify this standard
- And, to advance the standard to allow for the use of non-contact bumpers, (eg., laser ranging)



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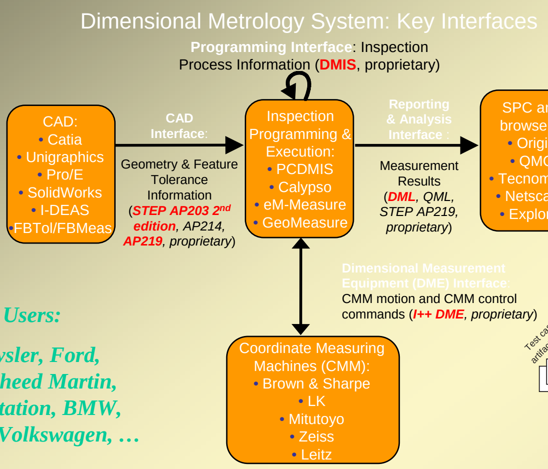
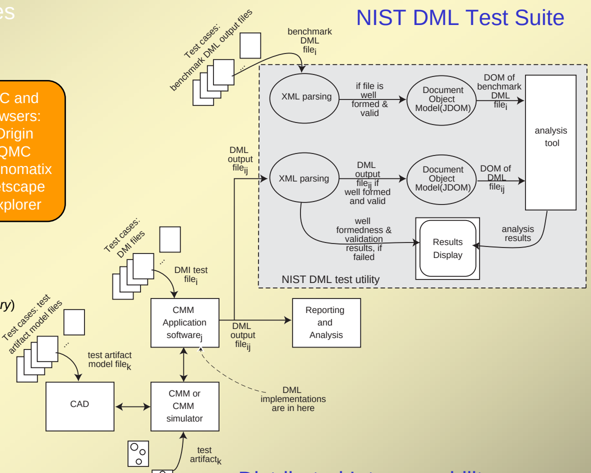
Metrology Interoperability





Participating Users:

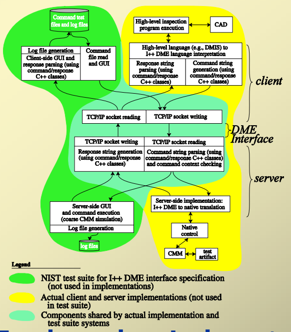
Daimler-Chrysler, Ford, Boeing, Lockheed Martin, GE Transportation, BMW, Volvo, Audi, Volkswagen, …

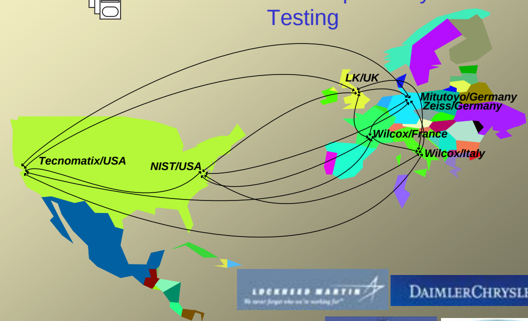
Participating Vendors:

Tecnomatix, Brown & Sharpe, LK, Zeiss, Leitz, Metromec, Wilcox, Metrologic, DCS, Mitutoyo, Renishaw, …

Three Key Organizations:

AIAG, I++, NIST



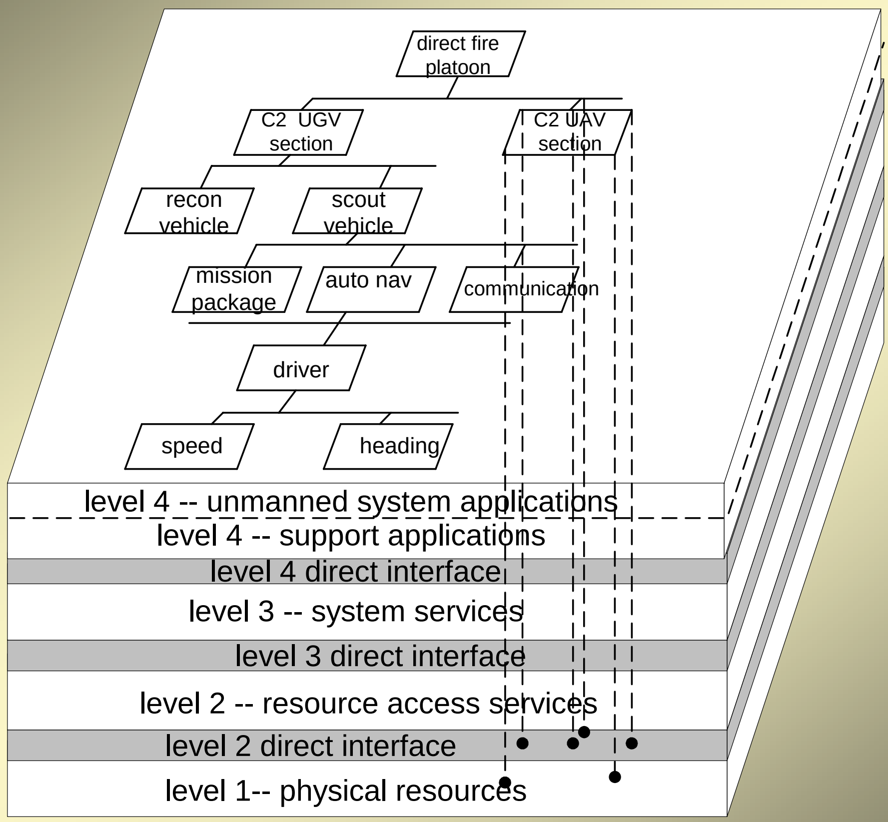


IV. Observations/Position for Robotic Standards

A. Generic Architectural Framework
B. Performance Metrics Framework
C. Taxonomy/Ontology

Standards Framework

4D/RCS Architecture Facilitating Standards

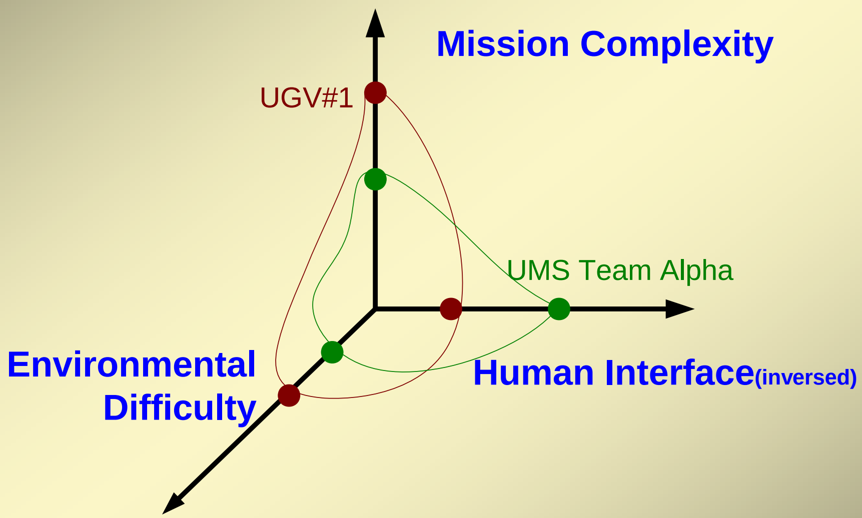


SAE GOA/ DOD TRM

Reference Model

- Systems, functions, entities, events, relationships
- Interaction and information flow between systems and subsystems
- Representations for knowledge, goals, plans, tasks, schedules, intentions, beliefs, values
- Housing for methods of perception, attention, cognition, reasoning, modeling, and learning

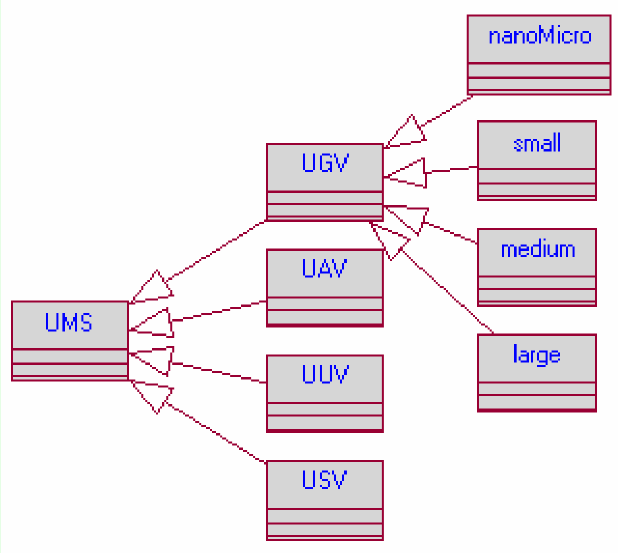
PERFORMANCE METRIC FRAMEWORK FOR UNMANNED SYSTEMS

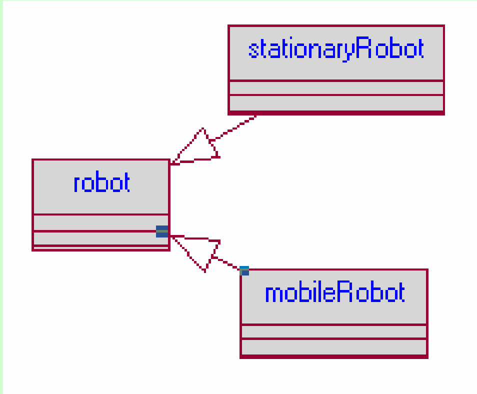


IV.D. Toward Robotic Taxonomy/Ontology

- Terms, Definitions, and Characteristics
- Categorization
  - UMS (next page)
  - Industrial robots: types of power sources, control, payload, mechanical configuration, DOF, application, etc. (ASTM F1034-86)

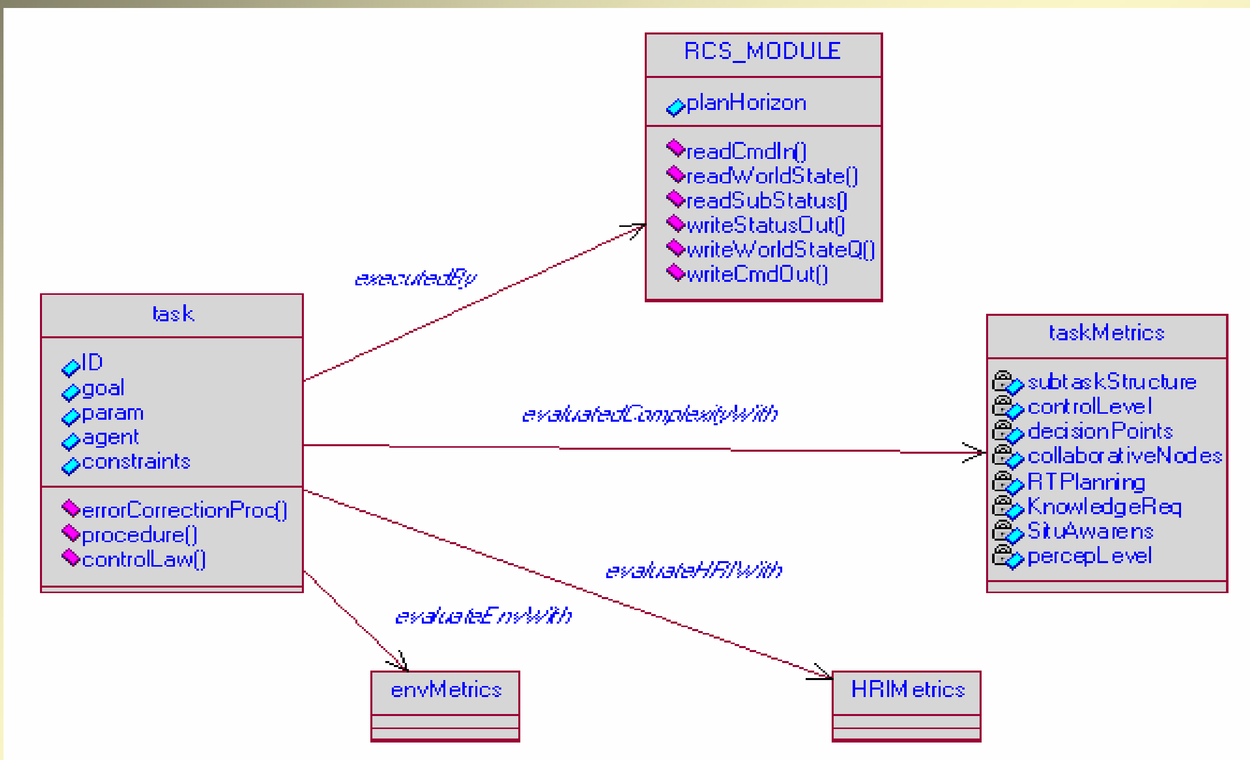
TOWARD UMS TAXONOMY/ONTOLOGY? Categorization





PerMFUS + 4D/RCS Env

TOWARD UMS TAXONOMY/ONTOLOGY? Integrated Relationships



TAXONOMY/ONTOLOGY? TERMS AND DEFINITIONS

ROBOT: An electro-mechanical system that can react to sensory input and carry out predetermined missions. … equipped with … tools or certain capabilities (and knowledge) … react to different situations …

UNMANNED SYSTEM (UMS): A electro-mechanical system, with no human operator aboard, that is able to exert its power to perform designed missions. May be mobile or stationary

NIST Special Pub 1011:

http://www.isd.mel.nist.gov/projects/autonomy_levels/publications/NISTSP_1011_ver_1.1.pdf

INDUSTRIAL ROBOT: An automatically controlled, reprogrammable multipurpose manipulator, programmable in three or more axes which may be either fixed in place or mobile for use in industrial automation applications. ANSI/RIA R15.06-1999

IV. Observations/Position for Robotic Standards

- Annual Performance Metrics for Intelligent Systems Workshop (PerMIS) Workshops

  http://www.isd.mel.nist.gov/PerMIS_2004
- ALFUS Workshops

http://www.isd.mel.nist.gov/projects/autonomy_levels/

ACKNOWLEDGEMENT

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- Nick Dagalagas, James Gilsinn, John Horst, ISD, NIST
- Dr. Jean Scholtz, Information Access Division, Information Technology Laboratory, NIST

Work Supported by DHS, ARL, and NIST STRS.

Would be glad to participate, contribute, and collaborate!

Thank You!

http://www.isd.mel.nist.gov

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Software-Based Communications

OMG Software Radio Specification Overview for Robotics

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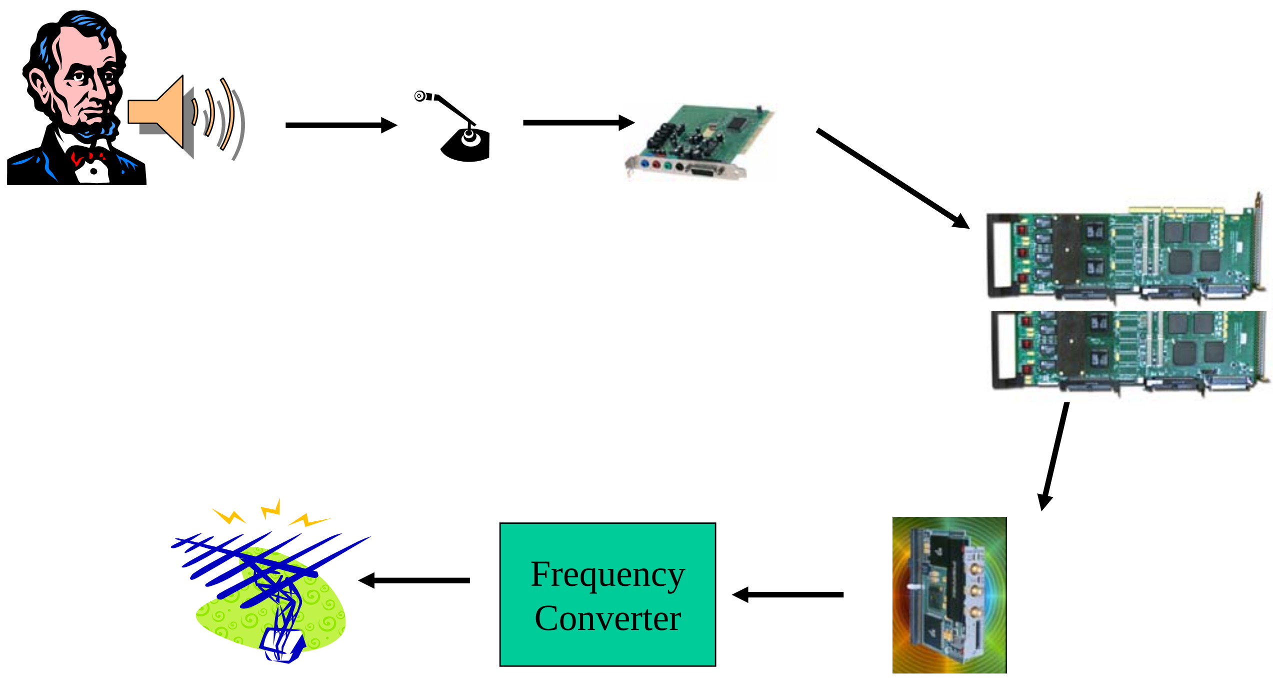
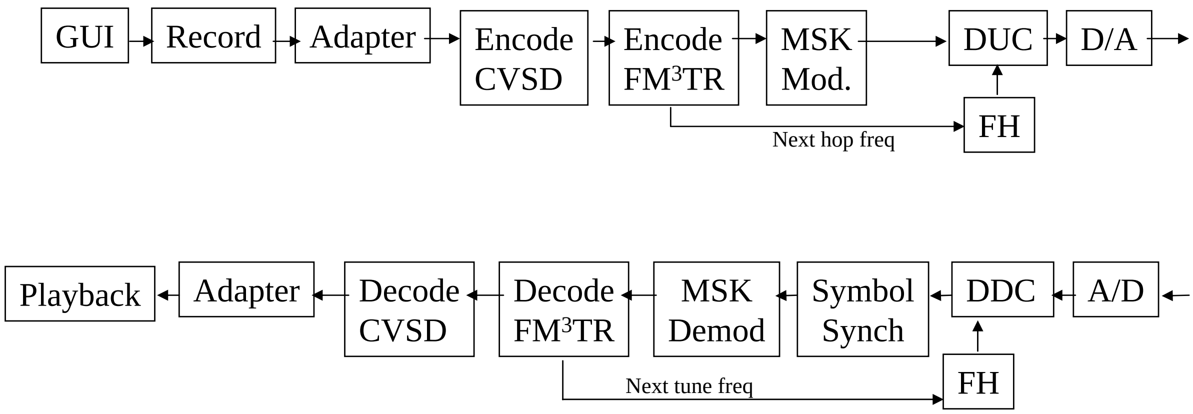
robotics/2005-01-06

Software-Based Communications

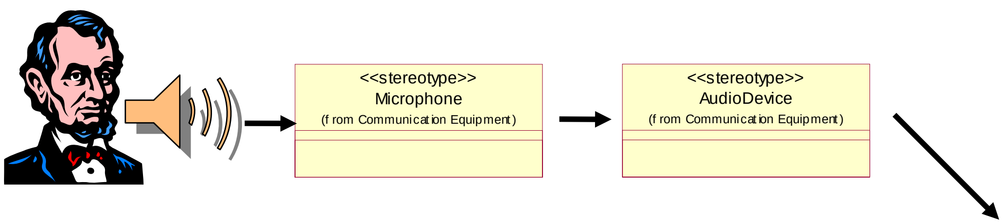
Communication Equipment – Real Life



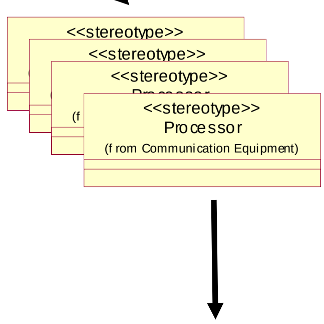
PIM Example: FM³TR (voice)

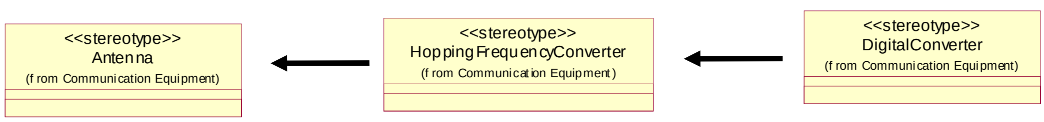


Communication Equipment – UML Profile Abstraction

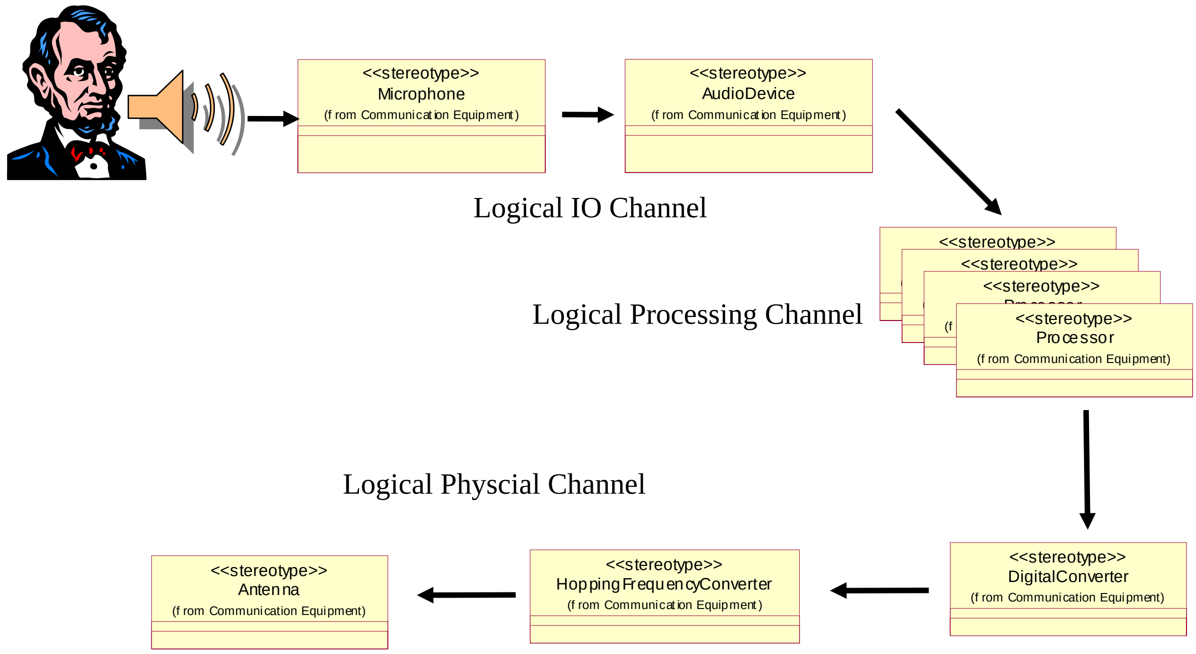


- Communication equipment elements can be interfaced by a DeviceDriver
- DeviceComponent is a logical device, and allows the infrastructure to create a generic SWRadioComponent on a CommEquipment device



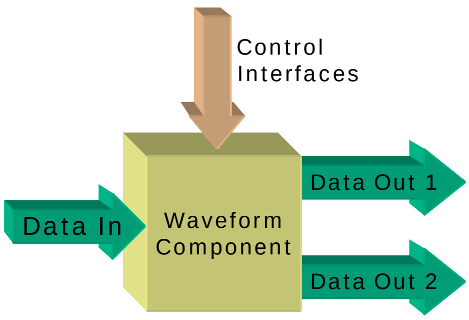


Locial Communication Channel Illustration



How are they used?

- Component based programming model
- Similar to Flow-Based Programming*
- Waveform elements realize control interfaces and achieve "*configurable modularity*"
- Waveform PIM definitions aim to provide a complete set of configuration parameters



* "Flow-Based Programming: A New Approach to Application Development", J. Paul Morrison, Thomson Publishing, 1994

Software-Based Communications

We have much in common

- OMG variants of existing standards
- Diverse remote devices
- Embedded, RT, frequently wireless performance
- Grew from interest, to SIG to Domain Task Force

Software-Based Communications

OMG SWRadio Specification Overview

- Domain Specific
  - SWRadio MDA Principles
  - SWRadio Development Viewpoints
  - UML Profile for SWRadio
  - SWRadio PIM Facilities
  - SWRadio PSM

- Domain Independent
  - Lightweight Services, Logging, CCM
  - Security “Suite”
  - Deployment and Configuration of Components
  - Smart Antennaes
  - DIF
  - …

SWRadio MDA Principles

- UML Profile for SWRadio extends UML for SWRadio tool support: validation, system engineering, and SWRadio component development
- PIM has been primarily structured as a set of facilities each addressing a key aspect of SWRadio
- Well-defined set of modeling conventions
  - Naming conventions
  - Modeling conventions
  - Subset of UML notation
  - Specific semantics of this notation in the context of this PIM
- Conforms to MDA
  - PIM can be transformed to different component platforms
    - CORBA-PSM, Java-PSM, etc.
- Compatible with existing OMG standards
  - MOF
  - UML

SWRadio Development Viewpoints

- To address the issues of the different actors involved in SWRadio product developments, the current profile was developed with three main viewpoints in mind:
  - the viewpoint of application and device developers,
  - the viewpoint of infrastructure/middleware providers, and
  - the viewpoint of SWRadio platforms providers.
- These three viewpoints define distinct sets of concepts (and stereotypes) that are required in different contexts.

UML Profile Overview

- Is a Type of UML package that is stereotyped as <<profile>>
  - Contains Extensions to metaclasses (M2 elements) such as components and property.
  - May contain other packages (like a package)
  - Can contain M1 elements such as specific class and/or interface definitions
  - Can contain associations of M2 elements to M1 elements.

Application and Device Components

- A set of component, interface, port, and property stereotypes definitions along with interface definitions to be used by SWRadio developers:
  - Device
  - Infrastructure
  - Service
  - Waveform

Application & Device Components Packages

- Base Types
  - Contains the common types for defining SWRadio components.
- Properties
  - Contains property stereotypes for SWRadio components
  - Configure, Query, Characteristic, Capacity
- Interface & Port Types
  - Contains the port and interface stereotypes for SWRadio interfaces and components
- Resource Components
  - Contains the interface and component stereotypes for waveform and device developers
  - ControllableComponent, LifeCycle, PropertySet, ResourceComponent, etc.
- Device Components
  - Contains the component stereotypes for device developers
  - Logical Device, Loadable and Executable
- Application Components
  - Contains the component stereotypes for application developers
  - Application, ApplicationResourceComponent, LayerResource (Data Link, MAC, Physical)

UML Profile for SWRadio Communication Equipment

- Stereotypes for SWRadio devices that are an extension of UML Device
- Communication Equipment describes the relationships and attributes that are appropriate for radio devices.
  - Crypto Device - performs encryption and decryption on asset of data.
  - I/O Device - describes the relationships and attributes that are appropriate for I/O devices
    - Antenna, Amplifier, Audio, Filter, Frequency Converter, etc.
  - Power Supply - provides electrical power to other devices.
  - Processor Device - processes digital or analog data.
- Port Types
  - Analog & Digital
- Property Types
  - Characteristic,Configure, and Query as described for Properties

UML Profile for SWRadio Infrastructure

- Communication Channel
  - Physical, IO, Security, and Processing Channel
  - Captures the relationships between channels and SWRadio devices
- Radio Services
  - Common services within the radio platform that are utilized by applications
  - Managed Service Component
- Radio Management
  - RadioSet, RadioSystem, and Device Management
- SWRadio Deployment
  - Components and Artifacts stereotypes for the deployment of:
    - Waveforms on communication channel's distributed devices
    - Radio Services within the Radio Set

Infrastructure – Communication Channel

- Data description for the collection and interconnection of the radio's devices necessary for a particular waveform application to be able to provide communication.
- Channel concept is an extension of UML Class that defines the relationships and attributes for channel types.
  - Is associated with one to many Communication Equipments. The types of Communication Equipments associated with a channel depends on the type of channel.

Communication Channel – Channel Stereotype Specializations

- LogicalCommunicationChannel is an aggregate of LogicalProcessingChannel, LogicalIOChannel and LogicalPhysical channel.
- LogicalPhysicalChannel stereotype consist of all devices processing the analog signal after digitization, to and including the antenna(s).
- LogicalProcessingChannel provides the processing nodes for waveform applications and radio services used by the waveforms running on the processing channel's operating environment(s).
- LogicalIOChannel provides for the baseband connection to the radio and consists of the devices that format, encode, decode, etc.
- LogicalSecurityChannel provides the processing node(s) for security applications applicable to communications.
- SecureLogicalCommunicationChannel specialization of LogicalCommunicationChannel that adds aggregation relationship to the LogicalSecurityChannel.

Infrastructure Radio Management – Radio Set

- Radio Set Components
  - DomainManager is a specialization of SWRadioComponent that provides domain retrieval operations
  - RadioManager is a specialization of DomainManager that manages a RadioSet
  - CommChannel is an extension of UML Component that manages a LogicalCommChannel.
- Radio Domain Interfaces that can be provided by a DomainManager
  - Domain Registration Management - provides the mechanism for registering and unregistering DeviceManager's services within a RadioSet.
  - Domain Installation Management - provides the mechanism for installing and uninstalling applications within a RadioSet.
  - Domain Retrieval - provides the mechanism for retrieving a radio's components.
  - Domain Event- provides the mechanism for managing RadioSet's event channels connections.

Infrastructure – SWRadio Deployment

- SWRadio Artifacts describes the SWRadio executable artifacts that are involved in the deployment of applications (e.g, waveforms), logical devices, and services within a SWRadio environment.
- Applications Deployment describes the components that are involved in the deployment of and management of SWRadio Applications

SWRadio Deployment – SWRadio Artifacts

- Extension of UML Artifact that indicates the type of loadable code
  - LoadableCode defines the base SWRadio artifact definition and relationships for any type of SWRadio artifact.
    - BITStream is object code for a prologic device (e.g., Field Programmable Gate Array device).
    - Library is loadable static or dynamic object code.
    - ExecutableCode is an executable operating system main process or entry point
      - LogicalDeviceExecutableCode is an executable operating system main process that manifests a DeviceComponent.
      - ResourceExecutableCode is an executable operating system main process that manifests either an SWRadio Resource or/andResourceFactory component.
      - ServiceExecutableCode is an executable operating system main process that manifests a Service.
  - Descriptor is a deployment or component specification that conveys information on the element to be deployed

Software-Based Communications

SWRadio Deployment – Applications Deployment

- ApplicationFactory
  - Specialization of SWRadioComponent
  - Deployment of Application component by Application's descriptor
  - Can manage capacities locally or delegate to device components.
- ApplicationManager
  - Specialization of ResourceComponent
  - Proxy for the deployed Application component
  - Provides basic operations for managing the deployed Application component.
    - Delegates ResourceComponent operations to Application's component internal assembly controller ResourceComponent
    - Can access deployed Application component ports

Software-Based Communications

SWRadio PIM Facilities

- Common Radio Facilities
  - Provides common service definitions that are applicable for all applications (waveforms or radio control)
  - File Services, OMG Lightweight Services (log, event, naming, etc.)
- Common Layer Facilities
  - Provides interfaces that cross cut through facilities that correlate to layers. These interfaces can be viewed as building blocks for SWRadio components that realize multiple interfaces.
  - Protocol Data Unit, Error Control, Flow Control, Measurement, Quality of Service, and Stream Facilities

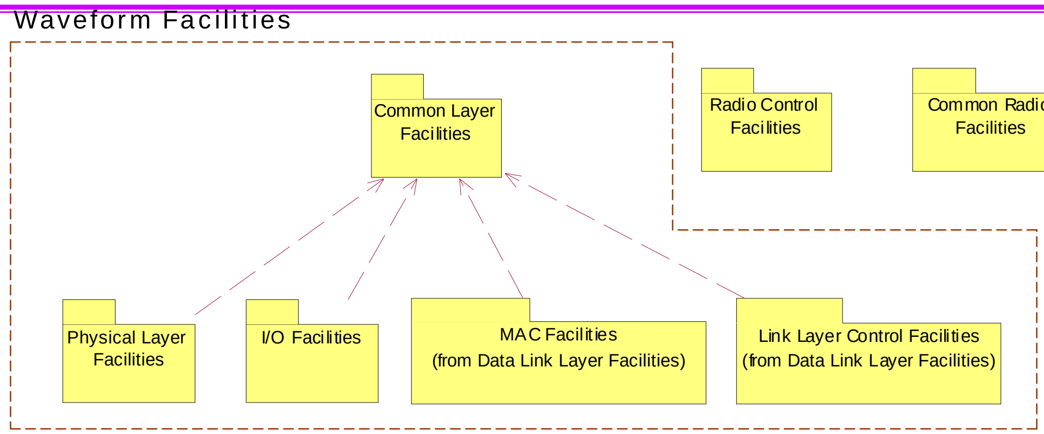
SWRadio PIM Facilities, cont'd

- Data Link Facilities
  - Link Layer Control (LLC) facilities. LLC layer provides facilities to upper layers, for management of communication links between two or more radio sets.
  - Data Link Layer (Connectionless, ConnectionLess Ack, Connection), and Medium Access Control Facilities
- I/O Facilities
  - Defines the configuration properties for Audio and Serial Facilities

SWRadio PIM Facilities, cont'd

- Physical Layer Facilities
  - Modem Facilities
    - The modem facilities include all digital signal processing elements required to convert bits into symbols and vice versa.
  - RF/IF Facilities
    - The RF/IF Facilities is used to configure and control the basic devices of the physical channel. The granularity at which these interfaces are implemented is not specified.
- Radio Control Facilities
  - Provides for interfaces for radio and channel management.

PIM Facilities



- Common Layer Facilities cut through layers
- Radio Control Facilities include channel management, radio management
- Common Radio Facilities are non-WF related services
- Physical, I/O, MAC, LLC are based on OSI definitions
- Common Layer, Physical and I/O facilities are for device

Waveform PIM

- Defines waveform related data and control interfaces
- Based on the “Extended” OSI Model*
- Semantic descriptions for the components realizing the interfaces
- Product of a survey of existing specs such as: 3GPP, DLPI, GLoMo, OBSAI, CPRI, 802.x, X.200e
- Why have a waveform PIM?
  - Change waveform parameters in run-time
  - Re-use existing components by using correct parameters
  - Allow portable code, different implementation of same components

* ISO 7498-1: Open System Interconnection – Basic Reference Model

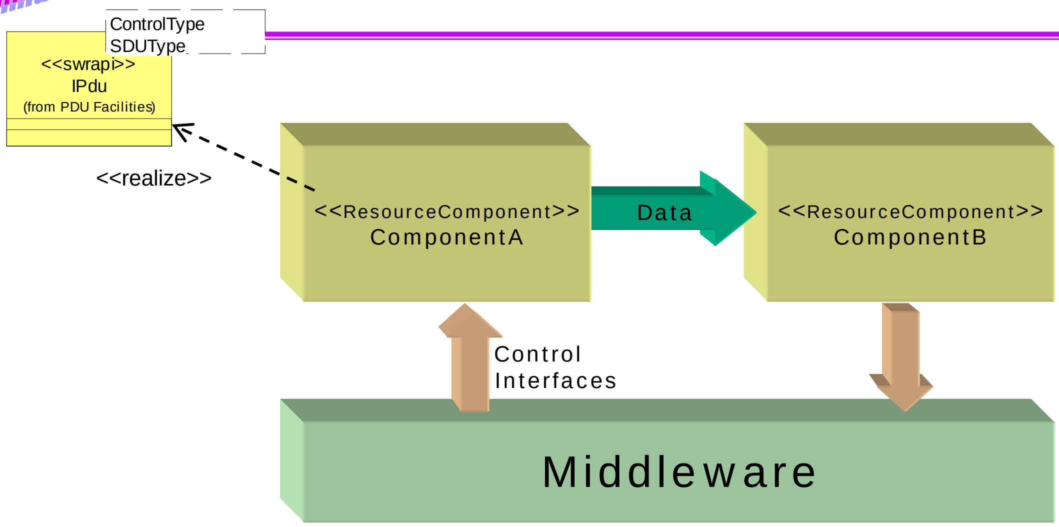
PIM: Physical Layer

- Interfaces on both control and data planes
- Most of the signal processing is done at this layer
- Provides parameterization of waveform algorithms for portable, modular code
- Used to control the communication equipment device attributes defined in the UML Profile
- Partitioned into:
  - Modem Facilities
  - RF/IF Facilities

PIM Example: Simple PDU

- A simple component example that realizes IPdu interface
- Stereotyped as <<ResourceComponent>>
- Has one output port
- Illustrates how a waveform component can be implemented by realizing the interfaces

Software-Based Communications



- ComponentA realizes IPdu interface, which inherits from ISimplePdu and IFlowControlSignalling interfaces
- It is stereotyped as a ResourceComponent, so it provides the required interfaces PortSupplier, PropertySet, ControllableComponent, etc. These interfaces are used in realizing swrapi's
- ComponentB can send flow control related signals to ComponentA, by using IPdu interface
- Another upstream component can control ComponentA to send its data using pushPdu operation
- Data can be marshaled by the middleware, or it can by-pass the middleware for performance reasons

Distributed Control and the Machine Bus Architecture

OMG Robotics Working Group

Introduction

- Chris Cooper, Software Architect at the Machine Bus Corporation.
- Machine Bus is a Chicago based company that specializes in distributed control systems for robotic and automated machinery applications.
- http://www.machinebus.com

Presentation Summary

- Distributed control architectures (DCA) for robotic systems
- Distributed control architecture and the product life-cycle
- What to expect from DCA in the near future

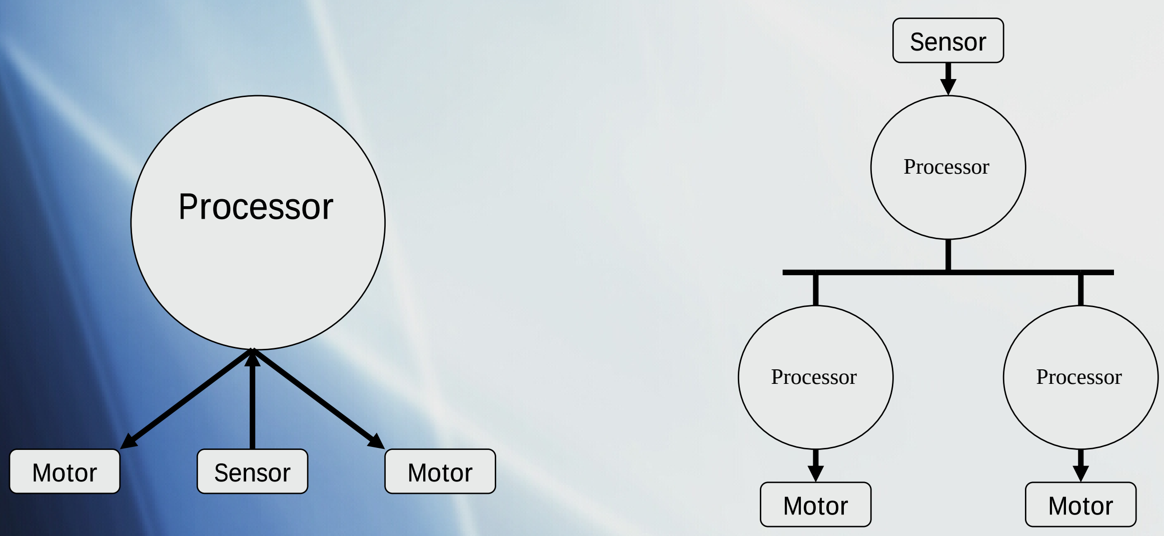
·Distributed Control Architectures for Robotic Systems

Definition, Benefits, and Selection

What is a distributed control architecture

- A distributed control architecture is a method of designing a control system in a way that spreads control functionality among many processing units
- This is in contrast to a centralized control architecture where all control functionality resides in a single processing unit
- Sensory input and actuation are coupled.

Distributed Control vs. Centralized Control



The Benefits of a Distributed Control Architecture

- Modular
- Reusable
- Scalable
- Extensible
- Reliable

DCA Benefit: Modularity

- Decompose complexity into smaller, more logical modules
- Object-oriented software maps well onto modular hardware
- Interfaces: prototyped modules can be swapped in/out with production optimized modules

DCA Benefit: Reusability

- Modular designs lead to reusability
- Functionally decomposed, fine grained modules can be reused within as well as across multiple applications
- Opens up a market for robotic hardware and software components

DCA Benefit: Scalability

- True parallel processing
- Increased real-time capacity
- Support for heterogeneous designs
- Avoid simulated processes that use context switching

DCA Benefit: Extensibility

- Add functionality by adding modules
- Devices with various I/O can be normalized.
- Integration of disparate systems
- Diagnostic and debugging equipment can be added
- Simulation possible

DCA Benefit: Reliability

- Modules are easier to test and verify correctness
- Reduced wiring complexity
- Redundancy
  - Processing nodes
  - Communication paths
- Partial failure

Polybot Example

QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

Courtesy of Palo Alto Research Center Inc.

- Modular
- Reusable
- Scalable
- Extensible
- Reliable

Selecting the Proper Platform

- Deterministic: Real-time capable
- Fault-tolerant
- Topology/Synchronization
- Development Environment

Platform Selection: Determinism

- Ability to be certain that an operation will complete within its allotted time frame
- Factors affecting determinism:
  - Medium access control
  - Data frame size
  - Data frame prioritization

Platform Selection: Fault Tolerance

- The ability to identify and recover from errors
- Hardware vs. software implementation
- Various type of Error detection
- Fault confinement
- Immunity to electrical noise

Platform Selection: Communication Structures

- How processing nodes are physically and logically connected affects performance and reliability
- Avoid single points of failure
- Extensibility and flexibility
- Activity coordination

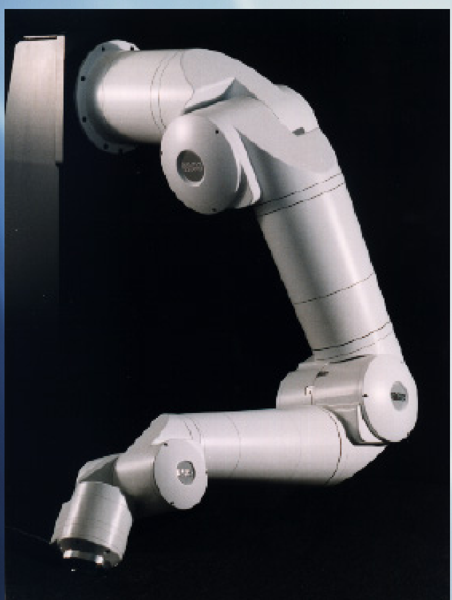
Platform Selection: Development Environment

- Rapid Application Development
- In-system programming
- Debugging and diagnostics
- Tool chain
- Language support

Distributed Control Architecture And the Product Life-Cycle

Scenario: A Robotic Arm

Scenario: A Robotic Arm



- A typical robotic arm
- Three degrees of freedom.
- One motor and one rotational encoder per joint.

The Product Life-Cycle

- Design Phase
- Production Phase
- Service in the field

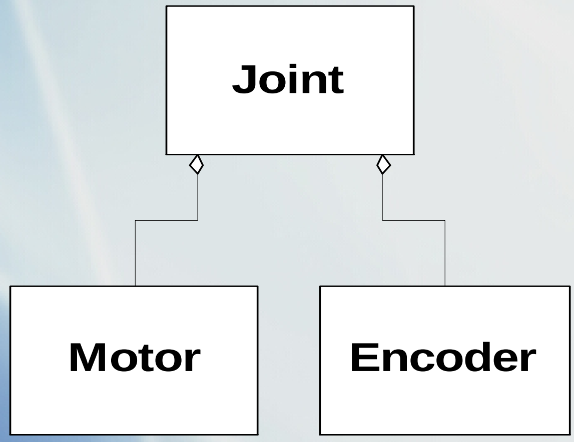
mBus™

Design Phase

- Control module design
- Application design
- Prototyping and testing

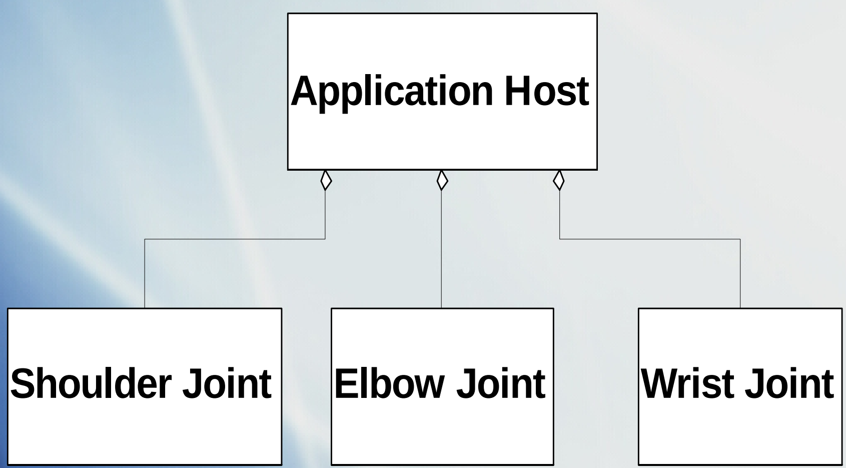
mBus™

Control Module Design



Joint Control Module

Application Design



Arm Application

Prototyping and Testing

- Simulation
- Testing frameworks
- Flexible redesign

Production Phase

- Optimization to reduce cost and size
- Quality control

Service in the Field

- Diagnostics
- Module replacement

Technology Affecting DCA in the near future

Application of Model Driven Architecture

- Open vendor neutral approach to system specification and interoperability
- MDA is a way to separate the architecture of an application from its implementation.
- In MDA, platform-independent models (PIM's) are initially expressed in a platform-independent modeling language, such as UML

Super Distributed Objects -

- A PIM for Distributed Control Architectures and Robotics?
- Attempts to model real world entities (e.g. devices) as objects, deploys them in a highly distributed environment
- Needs RT and a robotic domain profile (RFP work has just begun)

minimumCORBA

- a subset of CORBA designed for systems with limited resources.
- Are robotics devices too limited for minimumCORBA?
- Proxy approach (similar to JTRS and SCA's proxying of FPGA's)

Distributed Control and the Machine Bus Architecture

OMG Robotics Working Group

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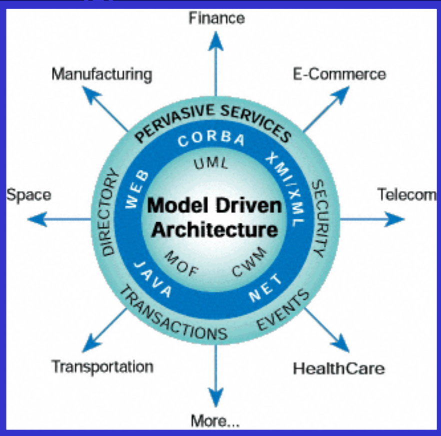

Model Driven Architecture Software Development in Robotics

September, 2004

Jon Siegel
Vice President, Technology Transfer
Object Management Group
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www.omg.org
+1 781-444-0404

What is OMG?

- Object Management Group - 15-year-old not-for-profit Computer Industry Standards Consortium
- Home of UML, the Industry's Modeling Standard
- and the Model Driven Architecture (MDA)
- Open Membership and Adoption Process
  - One-member, One-vote
- Specifications Available Free on our Website
- Buy Implementing Products from Vendors
  - Vendors may be OMG members, or may not
- Over 500 members including Companies, Government Agencies, Universities

Why Focus on Modeling?

Because Modeling is the only way to ensure that enterprise IT systems deliver the functionality that a business requires, comprehensive and stable, yet able to evolve in a controlled manner as business needs change over time.

Why Focus on Modeling?

Models built in the Unified Modeling Language (UML) represent exactly what a business application - even a complex, multi-platform integrated application - can do, and record it with a clarity and stability that far exceeds that of the applications themselves.

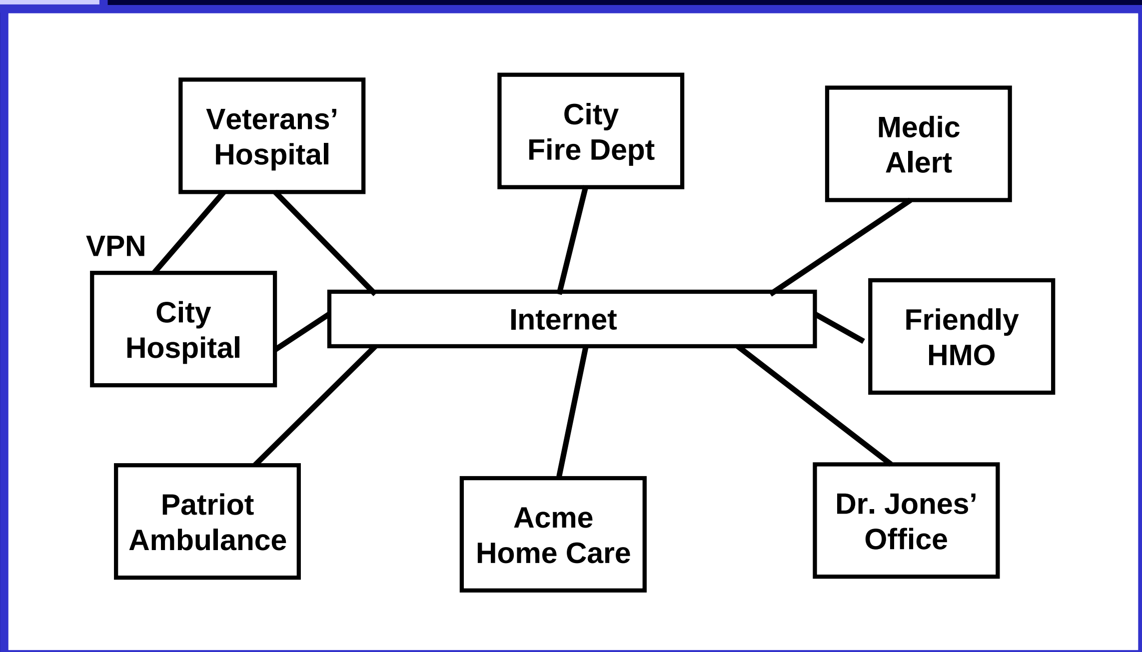
Why Focus on Modeling?

Based on technology-independent representations of their business functionality and behavior, modeled applications last for decades and maximize IT return on investment.

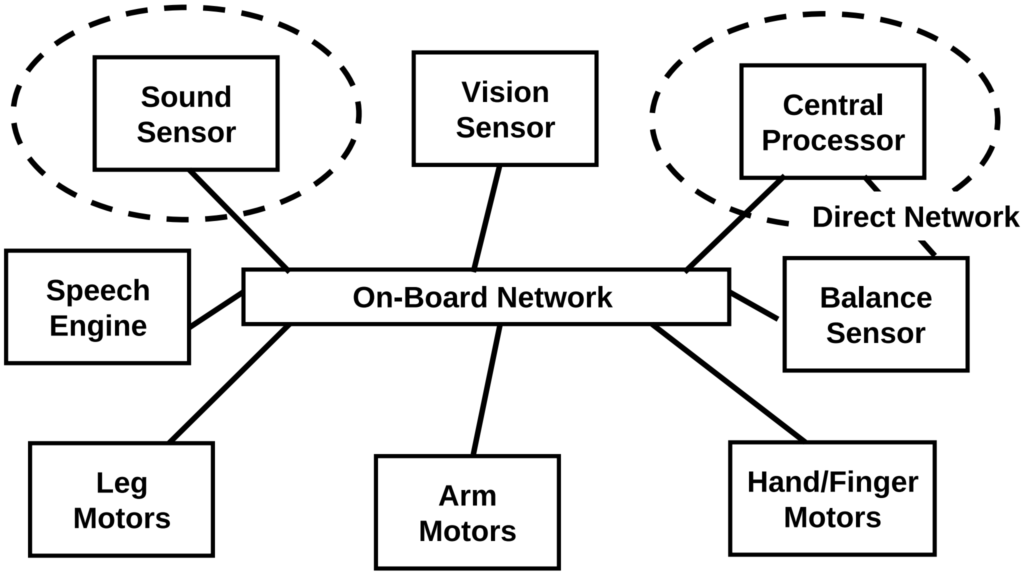
Jon Siegel, OMG: www.sdtimes.com/news/064/special1.htm

Object Management Group

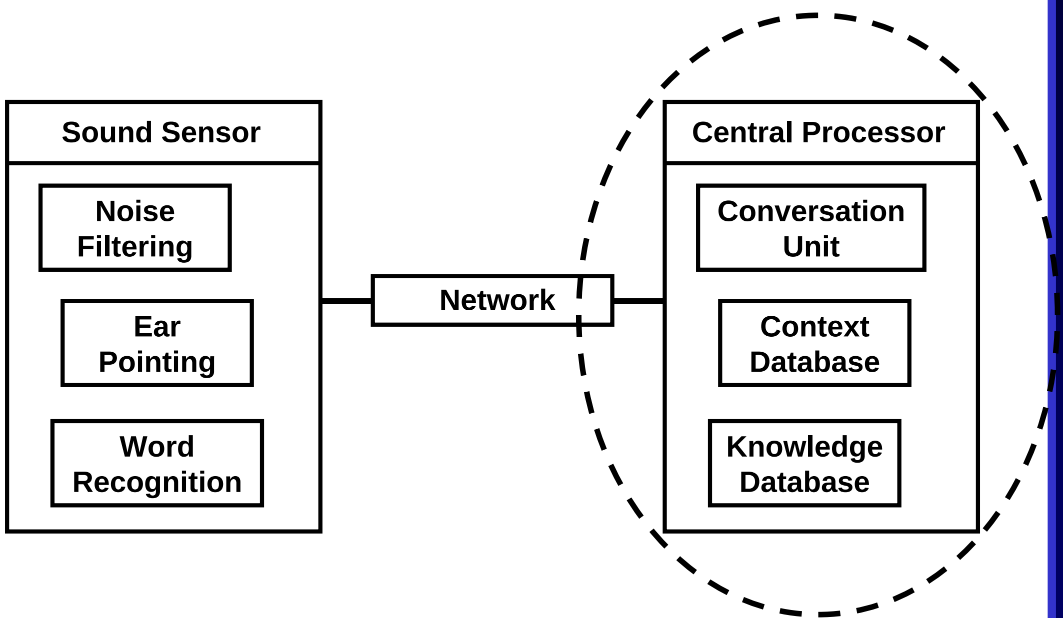
Architectural View



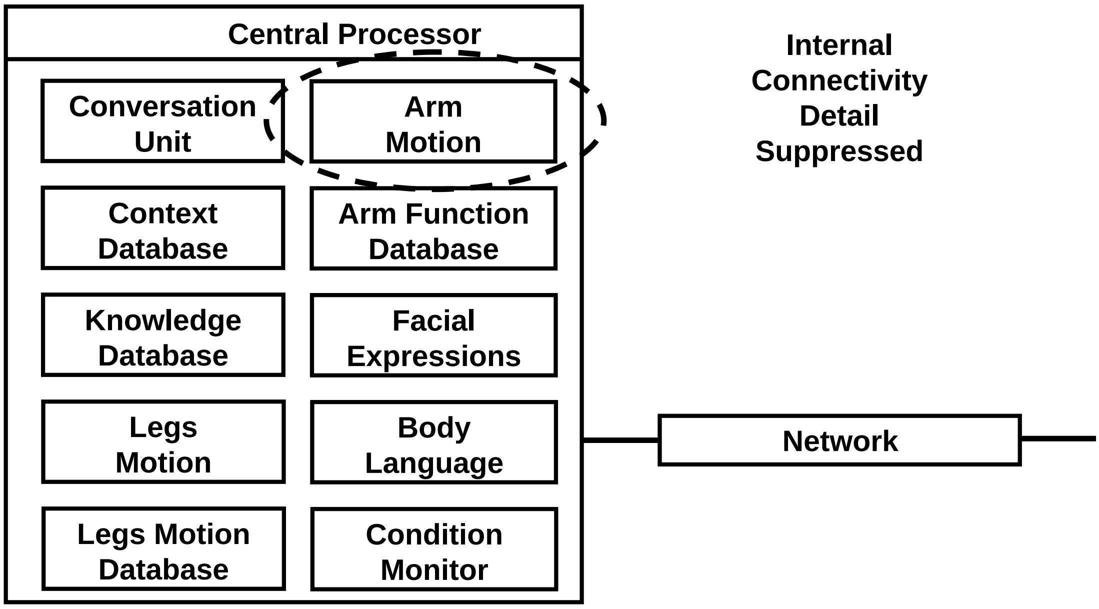
Robotics Version!



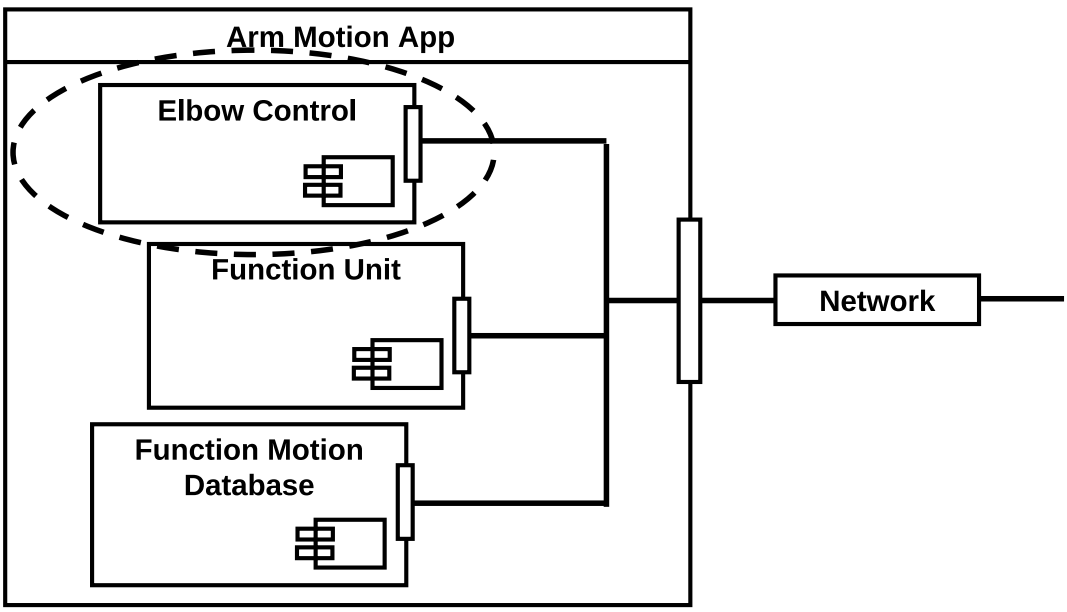
Zoomed In, Still Architectural



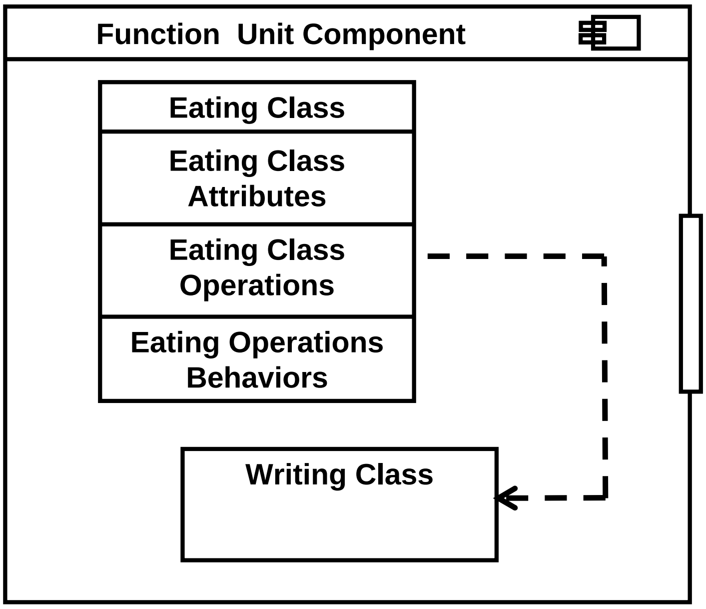
Enterprise Architecture View



Application Model



Component Model



Then MDA *Generates* the application *and its connectivity* from this detailed model

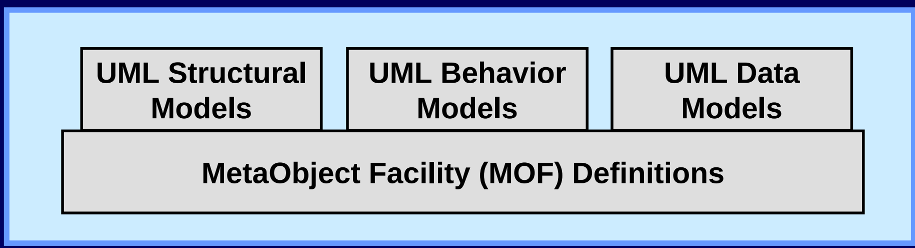
So you know that the application conforms to the model, connectivity works, and changes to any level model work in the real world

OMG Modeling Support

- MOF: Meta-Object Facility 2.0
  - Integrated Repository
  - Standard MetaModel
- Unified Modeling Language UML 2.0
  - World Standard for A&D
  - Representation for Structure, Dynamics, Deployment
- XMI: XML Metadata Interchange
  - Model & MetaModel Interchange
  - XML-Based Format, including DTDs
- CWM: Common Warehouse Metamodel
  - Data Warehousing Integration
  - Record, Table formats; Data Loading & Transformation

MOF - Foundation for Modeling

- MOF standardizes the basis for the elements that modeling languages define for you to model with
- Based on MOF, all of these diverse model elements can share repositories and interchange models among compliant tools:
  - Interchange of models and metamodels among toolsets
  - UML, MOF Itself, CWM, SPEM, XMI, UML Profiles
- And Especially, MOF supports the MDA!



UML – The Modeling Standard

- Integrates all the modeling you need to do
  - Functional and Business Modeling
  - Architectural/Deployment Modeling
  - Application Structure and Behavior
  - Component-Based Applications
  - Classes and Objects
  - Data Structures
  - Behavior, as State Machines, Data and Control Flow, Use Cases, more
  - The Industry Standard for Modeling

Start at Highest Level

- MDA *Raises the Level of Abstraction* with full connection from modeling to development
- Start with an Architectural Viewpoint of all your networked applications, and zoom in to a single application
- Also work from High Level Function and Process Viewpoint
- Then, model Structure and Behavior
- Finally, MDA tools *generate* your applications from your detailed application models

MDA – Two Benefit Areas

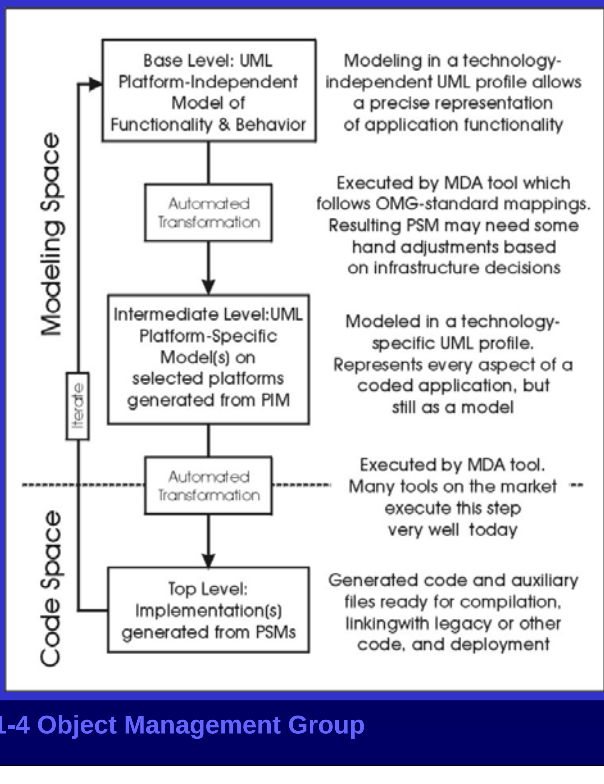
- The Design/Functionality Advantages:
  - Architectural Viewpoint brings out how your applications work with each other, and with those on the outside
  - Higher level of abstraction lets you define functionality and behavior separate from implementation
  - Define the Functionality and Behavior of each application as a technology-independent model
  - Focus your IT investment in defining core functionality, not in implementing it
- The Technological Advantages:
  - Interoperability and Portability are built into the MDA
  - MDA speeds development as it concentrates investment on functionality
  - Move easily to the next generation of robotics networking, or interoperate with it, quickly and easily

What is the Model Driven Architecture™?

- A New Way to Specify and Build Systems
  - Focus on Functionality before Technology
  - Based on Modeling and UML
  - Supports full lifecycle: A&D, implementation, deployment, maintenance, and evolution
  - Builds in Interoperability and Portability
  - Lowers initial cost and maximizes ROI
  - Applies directly to the mix of hardware and software that you face:
    - Programming language
    - Operating system
    - Network
    - *Middleware*

MDA: Designed for Efficiency

- Structure is a Spectrum progressing from Modeling at the Top to Code development at the bottom



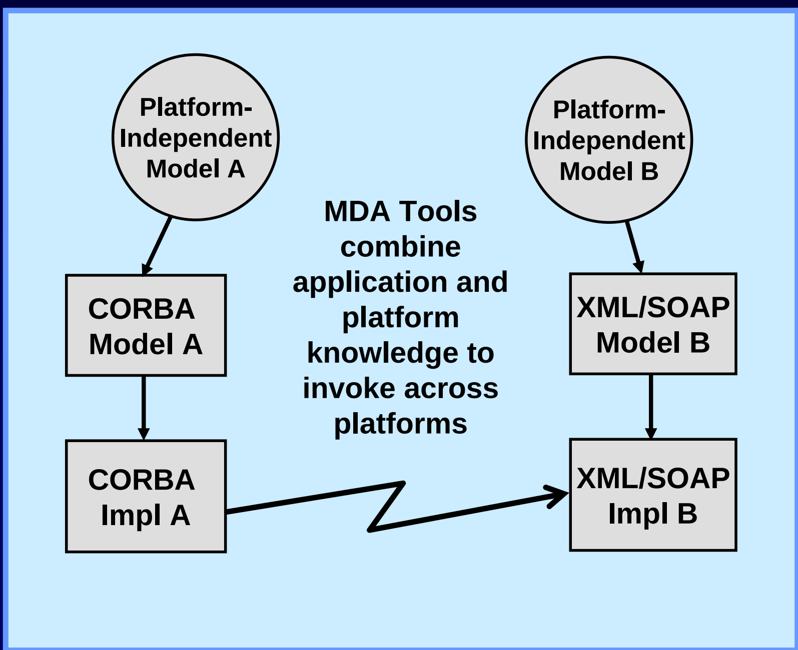
A Sensible Structure:

- Input and Investment concentrate at the functionality-defining zone at the top
- Automated tools take over coding IT infrastructure towards the bottom
- Code draws from libraries written and assembled by the industry's best minds
- Remote invocations, hard to program but hardly creative, are programmed by machines, not people

MDA Applications Interoperate

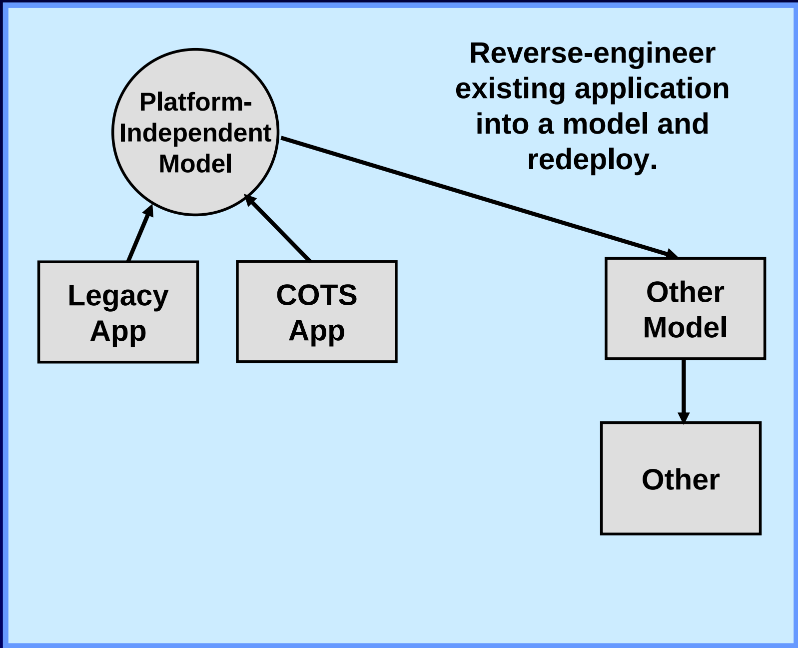
MDA Tools will generate cross-platform invocations connecting either instances of a single MDA application, or one application to another.

Standard *Pervasive Services* – directory, security, more – will also be accessed through cross-platform invocations where necessary.



Integrating Legacy & COTS

Tools for Reverse Engineering automate creation of models for re-integration on new platforms



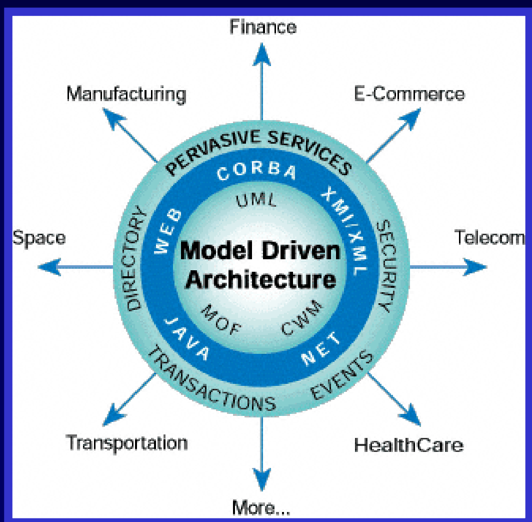
MDA in Industry Standards

OMG (and other) Task Forces standardize Domain (Industry-Specific) Facilities as PIMs.

With implementations on multiple platforms, no technology or platform barriers prevent widespread adoption and use.

Interoperate cross-platform with other standard applications.

Both PIM and set of PSMs and interface code – on *every* mapped platform – become OMG standards.



Robotics Standards at OMG

- OMG has launched an initiative to define Robotics standards based on the MDA
- Leaders include
  – NEDO (New Energy and Industrial Technology Development Organization; www.nedo.go.jp/english)
  – AIST (National Institute of Advanced Industrial Science and Technology; www.aist.go.jp/index_en.html)
  – Members of JARA (Japan Robot Association; /www.jara.jp/e/)
- Representatives have already held a series of Robotics Information Days and discussed organization at two OMG Technical Meetings

MDA Specifications

- MDA Architecture (September 2001)
- UML 1.5 (complete) and 2.0 (finalization)
- UML Profiles (all complete):
  – Profile for EDOC
  – Profile for EAI
  – Profile for CORBA
  – More…
- Support from XMI, CWM (complete)
- Pervasive Services (coming)
- Domain Specifications

MDA Benefits

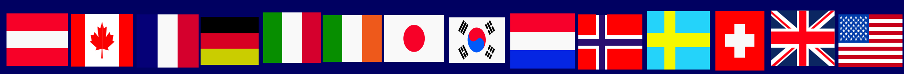
- Comprehensive architecture maximizes both business and technical advantages
- Technology-independent representation of business functionality and behavior
- Stable, model-based approach maximizes SW ROI
- Full support throughout the application life-cycle
- Reduced costs from beginning to end
- Reduced development time for new applications
- Optimized technical behavior - scalability, robustness, security – via generated code
- Smooth integration across middleware platform boundaries
- Rapid inclusion of emerging technologies into existing systems

OMG: Background

- About 500 member companies, world's largest software consortium.
- Founded April 1989 - Twelve Years Old
- Small staff (22 full time); no internal development. Representatives in Germany, Japan, U.K, Australia, India.
- Dedicated to creating and popularizing object-oriented standards for application integration based on existing technology.

Worldwide Scope

Alcatel	Computer Assocs	Fraunhofer Fokus	NEC	Siemens
Artisan	Compuware	HP	NIST	Software AG
BEA Systems	Daimler-Benz AG	Hitachi	Nokia	Sony
Bank of America	Deere & Co.	IBM	Northrup	Sun
Boeing Corp.	EDS	IONA	Oracle	Telelogic
Borland	Ericsson	Lockheed	PrismTech	Thales
BAE Systems	Fair Isaac	MetaMatrix	Raytheon	Unisys
CBOE	Fujitsu	Mitre	Sandia	W3C
Charles Schwab	GCHQ	Motorola	SAP AG	Workflow Mgmt



Meetings, Meetings!

- OMG Specifications are adopted at our meetings
- Held Five times a year, at member companies' sites around the world
- Lasts a week and attracts over 250 people
- Every subgroup meets; up to 30 simultaneous sessions on some days
- Dates, locations on the web at www.omg.org/news/schedule/upcoming.htm
- You're invited to come as an observer! Just let me know (email: info@omg.org)

Adoption Process

- RFI (Request for Information) to establish range of commercially available software.
- RFP (Request for Proposals) to gather explicit descriptions of available software.
- Letters of Intent to establish corporate direction.
- Submissions entered and revised.
- Task Force evaluation & recommendation; simultaneous Business Committee examination.
- Board decision based on TC and BC recommendations.

Availability

Innovative approach for selection of standard interfaces to adopt:

1. OMG adopts & publishes MDA PIMs and PSMs, and Implementation Interface Specifications.
2. Implementations of the Interface Specifications must be available commercially from OMG Platform, Domain, or Contributing member.
3. MDA PIMs and PSMs, and Interface Specifications, are freely available to members and non-members alike.
4. MDA PIMs and PSMs, and Interface Specifications chosen from existing products or prototypes in a competitive selection process.

OMG Links & Contacts

- OMG Homepage:
  - http://www.omg.org
- Download our specifications:
  - http://www.omg.org/specifications
- MDA Central:
  - http://www.omg.org/mda
- MDA Executive overview:
  - http://www.omg.org/mda/executive_overview.htm
- Find out about UML:
  - http://www/omg.org/uml
- Find out about CWM:
  - http://www.omg.org/cwm
- Contact OMG:
  - Email info@omg.org or siegel@omg.org

Future Robotics Group Activity

Tetsuo KOTOKU
AIST, Japan

January 31, 2005
Burlingame, CA

Robotics Standards at OMG

With the rapid progress in computer and communication technology, the robot systems are fast becoming larger and more complicated. Therefore, there is a real need for the software technologies for efficient developments. Now various software technologies are proposed and implemented respectively.

Rapid progress:

Computer Technology

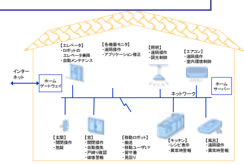
Network Technology

Robot Systems

- **larger**
- **more complicated**

Single robot

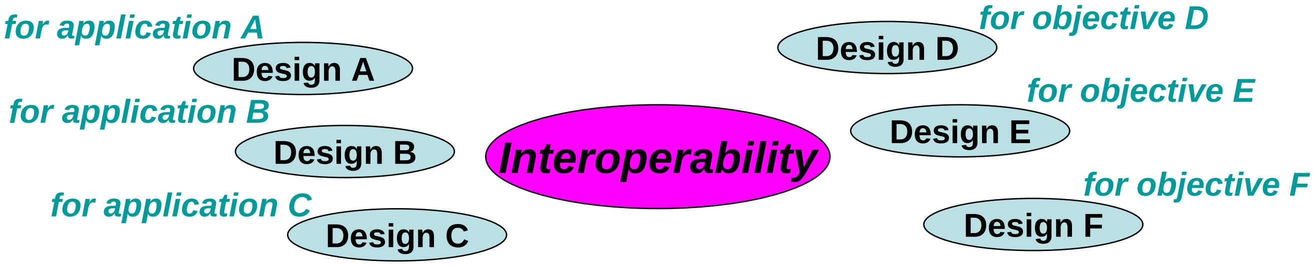
Networked robot



Efficient Development

Robotics Standards at OMG

Unfortunately, most of these pioneering initiatives are developed independently of the others, driven by specific applications and objectives. In order to settle this state of chaos, we would like to contribute to the promotion of standardization in the field of robotics based on the mutual understanding between the relevant parties.



Integration of robot systems based on modular components

Robotics standards based on the MDA

Robotics Standards at OMG

- At the previous Washington meeting, we established Robotics WG inside SDO-SIG to discuss the SDO model for robotic applications.
- While, for the general discussions on robotics domain. So we will make a motion of setting up new Robotics-SIG.

visible

Two activities in parallel

NATIONAL INSTITUTE OF ADVANCED INDUSTRIAL SCIENCE AND TECHNOLOGY (AIST)

Motion to Charter the Robotics Domain SIG

Co-Chairs (tentative):

- Makoto Mizukawa (Shibaura Institute of Technology)
- Tetsuo KOTOKU (AIST-Japan)

Mission:

The purpose of the Robotics Domain SIG is to foster the integration of robotics systems from modular components through the adoption of OMG standards. To realize this purpose, we will:

- Adapt and extend OMG technologies that apply to the specific domain of robotics systems where no current baseline specifications exist, such as MDA for Robotics. The object technology is not solely limited to software but is extended to real objects. This effort promotes the use of OMG technologies in various markets.
- Promote mutual understanding between the robotics community and the OMG community.
- Endeavor to collaborate with other organizations for standardization, such as the one for home information appliances, and make an open effort to increase interoperability in the field of robotics.
- Coordinate with the appropriate OMG subgroups and the Architecture Board, for technology areas that overlap with other OMG Task Forces, to determine where the work will be accomplished.

Next Meeting Agenda

April 11-15, 2005 (Athens, Greece)

Monday-Tuesday

SDO-SIG Meeting [Mon, Apr.11]

• SDO model applying to Robotics Domain (review RFP draft)

Robotics-SIG Meeting [Tue, Apr.12]

•Robotics Technology: initial survey (discussion of RFI draft)

Joint Meeting (SDO and Robotics)

Resources:

- Mailing List (robotics@omg.org)
  contact me (t.kotoku@aist.go.jp)
  or Nicole (nicole@omg.org)
- Presentations:
  http://www.omg.org/docs/
  - SDO (Super Distributed Objects) Meeting
    sdo/05-01-01 -> -08
  - Robotics Showcase
    robotics/05-01-01 -> -11

Home Page will come soon

Summary

We would like to kick-off the robot-related standardization activities in OMG.

Please keep in touch with each others and continue the discussion.

We appreciate your kind cooperation

Call for papers and participation

IEEE Workshop on Advanced Robotics and its Social Impacts (ARSO2005)

June 12-15, 2005

Nagoya, Japan

Planning OMG related Special Session

http://www.mein.nagoya-u.ac.jp/ARSO2005/

OMG Technical Meeting in Greece.

April 11-15, 2005

Athens, Greece

http://www.omg.org/registration/registration-info.html