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DOE/NIST Workshop on Common Architectures for Robotic Systems

Richard Quintero, Editor

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Robot Systems Division
National Institute of Standards and Technology
Gaithersburg, MD 20899

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ABSTRACT

At the request of the Department of Energy's (DOE's) Office of Technology Development the National Institute of Standards and Technology (NIST), Robot Systems Division organized and hosted this first DOE/NIST Workshop on Common Architectures for Robotic Systems. The Workshop was held at the Marriott Hotel in Gaithersburg, Maryland, on January 30-31, 1990.

This workshop had three goals:

(1) An initial review of the methodologies currently used by the DOE sites for development and maintenance of software related to robotic and remote systems.

(2) Presentations by representatives of other government agencies on lessons learned in the development of common architectures for robotic and remote systems.

(3) A preliminary assessment of the methodology necessary to arrive at a DOE common architecture.

DOE sponsored this workshop as a first step toward considering the potential roles and benefits that common robotic architectures could play in fulfilling DOE's Environmental Restoration and Waste Management (ER&WM) robotic technology program objectives. NIST hosted the workshop as a means of promoting robot technology advancement and technology transfer through the development of voluntary standards and guidelines.

KEY WORDS: control system architectures; intelligent machines; real-time control systems; robot control systems; robotic standards; robotics; teleoperation

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INTRODUCTION

At the request of Dr. Clyde Frank of the Department of Energy's (DOE's) Office of Technology Development the National Institute of Standards and Technology (NIST), Robot Systems Division organized and hosted this first DOE/NIST Workshop on Common Architectures for Robotic Systems. The Workshop was held at the Marriott Hotel in Gaithersburg, Maryland, on January 30-31, 1990.

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(2) Presentations by representatives of other government agencies on lessons learned in the development of common architectures for robotic and remote systems.

(3) A preliminary assessment of the methodology necessary to arrive at a DOE common architecture.

DOE's Office of Technology Development sponsored this workshop as a first step toward considering the potential roles and benefits that common robotic architectures could play in fulfilling DOE's Environmental Restoration and Waste Management (ER&WM) robotic technology program objectives. Potential benefits of common architectures include allowing robotic developments to be shared among DOE sites, thus lowering overall program costs, improving system reliability and maintainability, and accelerating technology insertion.

NIST's Robot Systems Division has been working in the area of sensory interactive control of intelligent machine systems for a number of years and is interested in promoting robotic technology advancement and technology transfer through the development of voluntary standards and guidelines.

Participation in this workshop was by invitation and was limited to a small group of DOE, NIST and other government agency representatives. Twenty-eight (28) people were in attendance. A follow-on workshop is planned for mid-summer 1990. This workshop will be attended by robotic technologists from DOE sites and other government agencies. The workshop will be aimed at developing a preliminary strawman of common robotic architecture guidelines which can be integrated into the DOE National Robotic Technology Development Program (NRTDP). Additional workshops will be held later in the calendar year, and beyond, to finalize the architectural guidelines, and to provide information to potential university and industrial participants.

Formal papers were not presented at this workshop. Instead, DOE operations office participants were asked to make presentations outlining their current software and control system development and maintenance procedures. Participants from other agencies gave presentations of lessons learned in similar robotic control system development efforts.

This proceedings includes the list of participants, the agenda for the workshop, a list of questions used to stimulate discussion in the working groups, a summary of the working group recommendations, their presentations and reprints of the presentations made during the first day of the workshop.

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Workshop on Common Architectures for Robotic Systems

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January 30-31, 1990

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WORKSHOP AGENDA

WORKSHOP ON COMMON ARCHITECTURES FOR ROBOTIC SYSTEMS

SCHEDULE

First Day	**Tuesday, January 30, 1990**
8:00	Late Registration
	Objective of This Workshop
9:00	Susan Prestwich, DOE - Purpose
9:10	Rick Quintero, NIST - Agenda
	DOE Environmental Restoration & Waste Management Program
9:20	Steve Cowan, DOE
	National Robotics Technology Development Program
9:40	Sam Meacham, ORNL - Applications
10:00	Patrick Eicker, SNL - Technology
10:20	Discussion
10:30	Break
	Software Methodologies for Robotic Systems in the DOE Complex
10:45	Clyde Ward, Savannah River Operations Office
11:05	Guy Armantrout, San Francisco Operations Office
11:25	Mark Evans, Richland Operations Office
11:45	Bill Hamel, Oak Ridge Operations Office
12:05	Lunch
1:30	Jim Seydel, Idaho Operations Office
1:50	Ray Harrigan, Albuquerque Operations Office
2:10	Discussion
2:30	Break
	Lessons Learned, Experiences
2:50	Jim Albus, NIST - NASREM/SARTICS
3:10	Brad Smith, NIST - IGES/PDES
3:30	Roger Schappell, Air Force - NGC
3:50	Discussion
	Preparation for Second Day
4:10	Rick Quintero, NIST - Review questions and charge working groups

Second Day **Wednesday, January 31, 1990**

	Discussion (See list of questions to be discussed)
8:00	Break-up into groups and begin discussions
	Development of recommendations
10:30	Develop Recommendations
11:00	Groups present recommendations
12:00	Lunch
1:30	Adjourn

WORKSHOP QUESTIONS

QUESTIONS TO BE ADDRESSED BY THE WORKSHOP ON COMMON ARCHITECTURES FOR ROBOTIC SYSTEMS

1. Why should DOE commit to developing a common open system architecture?

2. What are the high level functional requirements for an open system architecture?
   How important is each requirement and why?

3. How should the DOE develop technical requirements for an open system architecture?
   How specific should the requirements be?

4. How should the standards effort be coordinated?
   What type of standards committees should be formed?
   Who should participate?
   What steps should be taken?
   What standards organizations should be included and in what capacity?

5. How are such standards tested?
   How should new products be verified against the standard?
   How should the standard evolve?

WORKSHOP RECOMMENDATIONS

The first day of the workshop was devoted to presentations and discussion according to the agenda included above. Participants were divided equally into three working groups for the second day of the workshop. Jim Albus lead Group 1, Ray Harrigan lead Group 2 and Bill Hamel lead Group 3. The groups were assigned to separate meeting rooms and each group was asked to use the questions included above to stimulate discussion and to guide the development of their recommendations as follows:

Charge to the Working Groups:

> Answer the questions above and develop an outline of a plan for achieving a Common DOE Architecture. List the steps to be taken, milestones, possible participants and a strawman coordination scheme to initiate and further refine the plan.

At the end of the workshop the groups were reassembled in the main meeting room and each group presented their comments and recommendations. These presentations were transcribed and are included herein.

Groups 1 and 2 used the supplied questions to stimulate discussion but they did not attempt to specifically answer each question. Group 3 decided to rephrase the questions and then answer them in turn. Interestingly even though the groups approached the problem in very different ways they all converged on similar conclusions and recommendations.

The summary that follows attempts to combine the results produced by the three groups by using the rephrased questions produced by Group 3 and collecting the comments of all three groups with reference to each question.

0. SHOULD DOE/NRTDP PROMOTE GUIDELINES ON COMMON ARCHITECTURES FOR ROBOTIC SYSTEMS?

CONSENSUS: YES

> There was a strong consensus that the DOE environment is best served by a voluntary set of guidelines in contrast to a rigorous standard. The notion of a rigorous standard which might specify structural, hardware and software features of robotic system implementations was considered technologically premature and restrictive. There was concern expressed that a standard might evolve into regulatory specifications. A voluntarily set of guidelines which would emphasize methodologies was viewed as a valuable tool which could be used by DOE sites. This approach would provide robotic technologists with a framework to solve problems in a common manner, yet remain in a position to utilize the latest technology advances. Concern was also expressed regarding the current regulatory environment of the DOE complex and how standards might be used in ways which would restrict technical options.

1. WHY SHOULD DOE/NRTDP PROMOTE GUIDELINES ON COMMON ARCHITECTURES FOR ROBOTIC SYSTEMS?

PROS

NEAR-TERM

1. Guidelines would promote the exchange of technology and resources.

2. Guidelines should help to reduce implementation costs such as systems integration, training, etc. In short, guidelines would help make systems development faster, better, and cheaper.

3. Guidelines would allow the opportunity to leverage on-going work within DOE and other Government agencies (Navy, NGCR, NGC, NIST). Development of DOE guidelines might also allow DOE to influence the development of common architectures in other agencies.

4. Staff resources would be able to focus on solving higher level problems rather than recreating an infrastructure for each new project. New projects would tend to build on previous projects and add to a library of software resources.

LONG -TERM

5. DOE guidelines could help to induce commercial standardization of robotic control systems products.

6. As commercial standards evolve they would promote greater commercial competition, specialization and assimilation of the best technologies from a host of companies. Developers and technology users would be able to capitalize on U.S. strengths in advanced software development and entrepreneurship.

CONS

1. If the guidelines become mandatory standards they could potentially disrupt ongoing work or make nonstandard work obsolete.

2. Guidelines often become standards (regulations) within DOE which would constrain research and development at the DOE laboratories and operations sites.

3. Guidelines, if mandatory, could complicate modifications to existing systems.

4. By adopting guidelines (which are treated as mandatory standards in a regulatory environment) we can stifle movement to new technologies.

2. WHAT SHOULD THE CONTENT OF THESE GUIDELINES BE?

HOW IMPORTANT IS EACH REQUIREMENT AND WHY?

Working groups of technologists must be formed to develop the requirements early-on.

The short term goal of the common architecture definition effort should include developing a strawman set of METHODOLOGY GUIDELINES to include the following:

- FUNCTIONAL ARCHITECTURE PHILOSOPHY
- STRUCTURAL DECOMPOSITION "RULES"
- MODULE INTERFACE "PROTOCOLS"
- ROBOT LANGUAGE CONSTRUCTS

The methodology developed should:

- ALLOW LARGE AND SMALL SYSTEM DEVELOPMENT
- SUPPORT INDUSTRY STANDARD TECHNIQUES FOR SYSTEM DEVELOPMENT AND DOCUMENTATION
- APPLY TO HARDWARE AND SOFTWARE

Guideline development should strive toward:

- COMMON DESIGN AT MODULAR LEVEL SUCH THAT MODULES ARE INTERCHANGEABLE
- COMMON FAMILY OF HARDWARE COMPONENTS

In the long-term sites with common ER&WM problems should be able to capitalize on common software and hardware solutions.

3. WHAT ARE THE FIRST LEVEL RECOMMENDATIONS WHICH COULD BE FORMULATED FOR THESE GUIDELINES?

User working groups should be formed to develop a set of recommended software development tools, by consensus. The intent of these recommendations would be to communicate to developers and users a common set of development tools which they could employ on a voluntary (optional) basis. Tool set recommendations should include:

- PROGRAMMING LANGUAGES
- OPERATING SYSTEMS
- COMPUTER AIDED SOFTWARE ENGINEERING (CASE)
- DOCUMENTATION SYSTEM FORMATS
- HARDWARE (CPUS, BUS)
- THE USE OF COMMERCIAL EQUIPMENT

4. HOW SHOULD THE GUIDELINES BE FORMULATED, PROMOTED, COORDINATED?

WHAT TYPES OF COMMITTEES SHOULD BE FORMED?
WHO SHOULD PARTICIPATE?
WHAT STEPS SHOULD BE TAKEN?
WHAT ORGANIZATIONS SHOULD BE INCLUDED AND IN WHAT CAPACITY?

The Oak Ridge and Sandia Laboratories have been tasked to develop a National Robotics Technology Development Plan (NRTDP) by the DOE Office of Technology Development. It was recommended that they be assigned to coordinate the development of the common architecture guidelines as part of the NRTDP effort with support from NIST. An early priority for the NRTDP team should be to collect DOE robotic system project requirements from the operations sites (project managers, technical support staff) and the laboratory technologists.

It was recommended that a task identification team be established to recommend common robotic systems solutions in five areas as follows:

- UNDERGROUND STORAGE TANKS
- BURIED WASTE SITES
- DECOMMISSION AND DEMOLITION
- AUTOMATIC LAB ANALYSIS
- HEAVY MACHINERY

The NRTDP team should coordinate the following efforts:

- Collect Project Requirements.
- Identify common ER&WM problems.
- Establish Working Groups.
- Develop REV 0 Methodology Guidelines and distribute for comment.
- Coordinate a series of workshops.
- Develop a long term NRTDP strategy encompassing the development of common architecture guidelines and a mechanism for maintaining and updating the guidelines.

User working groups should be formed (e.g., DOE SUBWOG Group) to develop a REV 0 preliminary version of the common architecture guidelines to be distributed for comment preferably before the next workshop (Workshop #2). It was suggested that the group could meet at Sandia in 2 or 3 months. These working groups should be made up of DOE technologists from the laboratories and the operations sites.

People from the working groups should be designated as DOE representatives (an on-going coordinating committee) to attend meetings of other government agency common architecture bodies (e.g., NGC, NGCR, NIST, BOM, etc.) in order to leverage and influence their efforts.

The coordinating committee should also be cognizant of the activities of existing standards organizations such as:

- RIA
- ASTM
- IEEE
- ASME

It was suggested that the technical users groups could communicate by using E-MAIL and through quarterly meetings while they are defining requirements and guidelines.

5. HOW SHOULD THE GUIDELINES EVOLVE/UPDATE?

The NRTDP team should be assigned to develop a long-term strategy for maintaining, updating and distributing the common architecture guidelines.

In the near term it was recommended that a series of workshops be planned in conjunction with the development of requirements and the development of guidelines as follows:

TIMING:

MONTH 0 - January 30-31, 1990

- WORKSHOP #1

IN 3 MONTHS - May 1990
Using a working group of DOE technologists and support from NIST and based on prior experience as well as current and ongoing projects, the following should be developed:

- STRAWMAN Recommendations
- FIRST-CUT Site requirements and preliminary concepts
- Issue PRELIMINARY GUIDELINES

IN 4-6 MONTHS - June-August 1990
Using approximately the same internal people plus NIST, NGC and NGCR representatives

- WORKSHOP #2 to review first set of concepts

IN 6-8 MONTHS - August-October 1990
Issue for review the results of WORKSHOP #2 and the latest versions of the project requirements document

IN 8-11 MONTHS - October/90-January/91
Hold a workshop to produce Preliminary Guidelines REV 1

- WORKSHOP #3 include university participants as well as DOE, NIST, NGC and NGCR participants

BEYOND 12 MONTHS - February 91

- WORKSHOP #4 bring in industry participants in addition to university, DOE, NIST, NGC and NGCR participants

In the long term any research and development products developed under the NRTDP (using the common architecture guidelines) must be demonstrated and accepted. This means that it will be very important to interface with operations site engineering development group.

GROUP 1 PRESENTATION

0. DOE SHOULD IDENTIFY A PREFERRED OPEN SYSTEMS ARCHITECTURE TO BE APPLIED WHERE APPROPRIATE, I.E., WHERE COMMON PROBLEMS EXIST.

1. WHY?

    - FASTER, BETTER, CHEAPER, MORE RELIABLE
    - TECH TRANSFER
        - SHARE SOLUTIONS -- LESSONS LEARNED
        - BUILD ENHANCEMENTS

2. WHAT?

    METHODOLOGY THAT:
    - ALLOWS LARGE AND SMALL SYSTEM DEVELOPMENT
    - SUPPORTS INDUSTRY STANDARD TECHNIQUES FOR SYSTEM DEVELOPMENT AND DOCUMENTATION
    - APPLIES TO HARDWARE AND SOFTWARE

    STRIVE TOWARD:
    - COMMON DESIGN AT MODULAR LEVEL SUCH THAT MODULES ARE INTERCHANGEABLE
    - COMMON FAMILY OF HARDWARE COMPONENTS

    COMMON SOLUTIONS BRIDGING MULTIPLE SITES SHOULD HAVE COMMON HARDWARE AND SOFTWARE

3. HOW?

    TASK IDENTIFICATION TEAM TO RECOMMEND COMMON SOLUTION

    5 AREAS:
    - UNDERGROUND STORAGE TANKS
    - BURIED WASTE SITES
    - DECOM AND DEMOLITION
    - AUTO LAB ANALYSIS
    - HEAVY MACHINERY

    IDENTIFY COMMONALITIES

    DEVELOP TECH REQUIREMENTS

4. ESTABLISH ONGOING COORDINATING COMMITTEE OF TECHNICAL WORKING PEOPLE INCLUDING ALL SITES + OBSERVERS AND ADVISORS
    - NIST
    - BOM
    - ETC.

5. N/A

GROUP 2 PRESENTATION

1. OPEN ARCHITECTURES

- NEEDS DEFINITION
- AT THIS STAGE THE FOCUS SHOULD BE ON COMMON
    - MODULES
    - USE OF COMMERCIAL EQUIPMENT
    - STANDARD HIERARCHIES
    - MULTIPLE

2. GROUP INTERACTIONS

- EXISTING STANDARDS ORGANIZATIONS
- RIA
- ASTM
- IEEE
- ASME

- DOE SUBWOG TYPE GROUPS
- MEET SOON AT SANDIA? (2-3 MOS.)

- TECH GROUP COMMUNICATIONS
- EMAIL
- QUARTERLY MEETINGS
- DEFINE REQUIREMENTS

- ASSIGN GROUP SPOKESMAN TO INTERACT WITH STDS ORGS
- NIST?
- TECH GROUPS(?)

3. GETTING R&D ADOPTED

- R&D MUST DEMONSTRATE TECHNOLOGY
- INTERFACE WITH SITE ENGR. DEVEL. GROUPS

GROUP 3 PRESENTATION

QUESTIONS TO BE ADDRESSED
BY
THE WORKSHOP ON COMMON ARCHITECTURES FOR
ROBOTIC SYSTEMS

0. SHOULD DOE/NRTDP PROMOTE GUIDELINES ON COMMON R. ARCHITECTURES? YES.

1. WHY SHOULD DOE/NRTDP PROMOTE A COMMON OPEN ARCHITECTURE? NEAR-TERM PROS AND LONG-TERM PROS

PROS

NEAR-TERM 1) PROMOTE EXCHANGE OF TECHNOLOGY/RESOURCES

NEAR-TERM 2) SHOULD REDUCE IMPLEMENTATION COSTS (SYS. INTEGR., TRAINING)

NEAR-TERM 3) ALLOWS OPPORTUNITY TO LEVERAGE AND INFLUENCE ONGOING WORK WITHIN DOE AND OTHER GOV. AGENCIES (NGCR, NIST, NAVY).

4) IN LONG-TERM, WOULD INDUCE COMMERCIAL STANDARDIZATION OF ROBOTIC CONTROL PRODUCTS.

5) GREATER COMPETITION, SPECIALIZATION, AND INCORPORATION OF BEST TECHNOLOGIES FROM A HOST OF COMPANIES (E.G., CAPITALIZE ON STRENGTHS IN ADVANCED SOFTWARE AND ENTREPRENEURSHIP).

NEAR-TERM 6) STAFF RESOURCES FOCUS ON SOLVING PROBLEMS RATHER THAN RE-CREATING INFRASTRUCTURE.

CONS

1) DISRUPTION/OBSOLESCENCE OF ONGOING WORK
2) GUIDELINES OFTEN BECOME REGULATIONS WHICH WOULD CONSTRAIN R&D AT SITES
3) MAY COMPLICATE MODIFICATIONS TO EXISTING SYSTEMS
4) BY ADOPTING GUIDELINES (WHICH ARE TREATED IN A "REGULATORY" ENVIRONMENT),WE CAN STIFLE MOVEMENT TO NEW TECHNOLOGIES.

2. WHAT SHOULD THE CONTENT OF THESE GUIDELINES BE? HOW IMPORTANT IS EACH REQUIREMENT AND WHY? REQS. NEEDED!

3. WHAT ARE THE FIRST LEVEL RECOMMENDATIONS WHICH COULD BE FORMULATED FOR THESE GUIDELINES?

SHORT TERM

- METHODOLOGY <u>GUIDELINES</u>:
  - FUNCTIONAL ARCHITECTURE PHILOSOPHY
  - STRUCTURAL DECOMPOSITION "RULES"
  - MODULE INTERFACE "PROTOCOLS"
  - ROBOT LANGUAGE CONSTRUCTS

- RECOMMENDATIONS-TOOLS (OPTIONAL)

USER WORKING GROUP

- PROGRAMMING LANGUAGES
- OPERATING SYSTEMS
- COMPUTER AIDED SOFTWARE ENGINEERING (CASE)
- DOCUMENTATION SYSTEM FORMATS
- HARDWARE (CPUS, BUS)

<u>ISSUES/STRATEGY</u>

LONG TERM --- <u>ASSIGN TO NRTDP</u>

- RECOMMENDATION THAT NRTDP HAVE REP ATTEND THESE MEETINGS {NGC, NGCR, NIST} -- GOALS AND OBJECTIVES

- GET PROJECT REQUIREMENTS

4. HOW SHOULD THE GUIDELINES BE FORMULATED, PROMOTED, COORDINATED?
   - WHAT TYPE COMMITTEES SHOULD BE FORMED?
   - WHO SHOULD PARTICIPATE?
   - WHAT STEPS SHOULD BE TAKEN?
   - WHAT ORGANIZATIONS SHOULD BE INCLUDED AND IN WHAT CAPACITY?

<u>PRELIMINARY GUIDELINES FOR CRA</u> - 1ST GENERATION <u>REV 0</u>

WHAT? TECHNICAL APPROACH

HOW? ORGANIZATIONAL PERSPECTIVE

SEE GANTT CHART (FIGURE 1)
WORKSHOP #2
ATTENDEES: TECHNOLOGISTS
PROGRAM/PROJECT KEEPERS

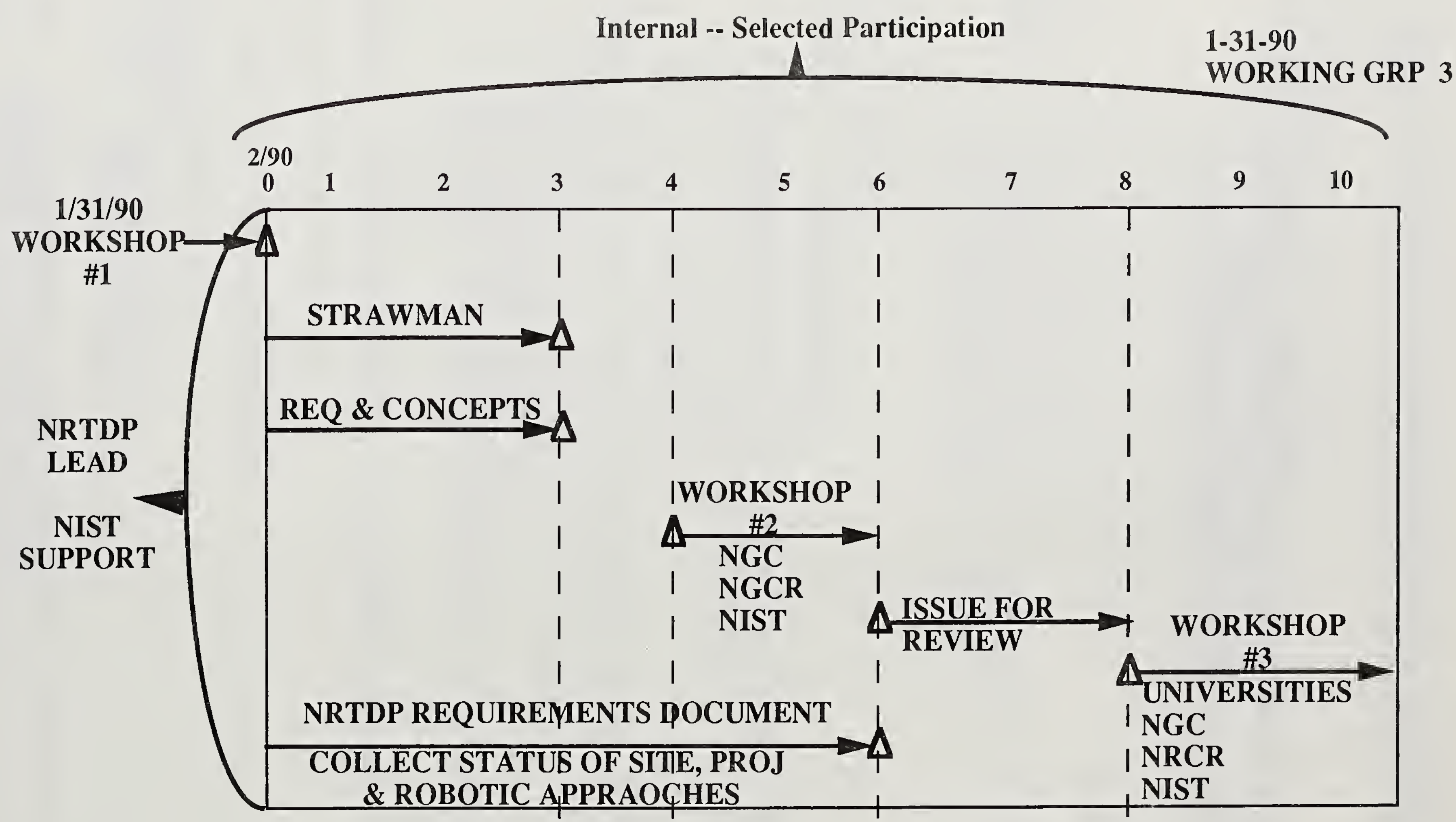
NT: DEVELOP METHODOLOGY GUIDELINES & RECOMMENDATIONS FROM STRAWMAN DEV. BY NRTDP (+NIST)
LT: DEVELOP STRATEGY FROM STRAWMAN DEV. BY NRTDP (+ NIST, NGC)

5. HOW SHOULD THE GUIDELINES EVOLVE/UPDATE?

TIMING:

IN 3 MONTHS - INTERNAL TO TECHNOLOGISTS, PRIOR EXP. ONGOING PROJ
- STRAWMAN
- FIRST-CUT SITE REQMTS. AND PRELIM. CONCEPTS
- ISSUE PRE. GUIDELINES

IN 4-6 MONTHS
- WORKSHOP #2



WORKSHOP # 1 1/30-31/90; Kick-off Meeting Common Architecture Guidelines
WORKSHOP # 2 In 4 -6 months; Working meeting for Technologists
WORKSHOP # 3 In 8 to 11 months; Produce Preliminary Guidelines
WORKSHOP # 4 Beyond 12 months; Industrial Participation?
University Participation?

FIGURE 1

FIRST DAY PRESENTATIONS

PRESENTATION BY SUSAN PRESTWICH

FOR D.O.E./N.I.S.T. WORKSHOP

ON COMMON ARCHITECTURES FOR

ROBOTIC SYSTEMS

1/31/90

GOOD MORNING. I APPRECIATE THE OPPORTUNITY TO WELCOME YOU TODAY TO THIS IMPORTANT WORKSHOP ON COMMON ARCHITECTURES FOR ROBOT SYSTEMS AND TO CLEARLY IDENTIFY THE ENERGY DEPARTMENT'S EXPECTATIONS OF WHAT CAN AND SHOULD BE ACCOMPLISHED BY THE END OF THIS WORKSHOP.

FOR THE PAST SEVERAL MONTHS OFFICIALS FROM THE DEPARTMENT OF ENERGY HAVE BEEN DISCUSSING THE **ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT 5-YEAR PLAN**, AND PARTICULARLY, THE **RESEARCH AND DEVELOPMENT** CHAPTER OF THAT PLAN, WITH THE PUBLIC, ACADEMIA, CONGRESS, AND SELECTED GOVERNMENT AGENCIES. ON EVERY OCCASION WE HAVE BROUGHT TO THE FOREFRONT THE COUNTRY'S NUCLEAR WEAPONS COMPLEX AS A PERFECT ILLUSTRATION OF WHAT HAPPENS WHEN WE DON'T ANTICIPATE LONG-TERM ECONOMICS, UNDERINVEST IN THE FUTURE, AND LOSE SIGHT OF THE FULL SCOPE OF OUR MISSION.

SO THAT ALL OF US BETTER UNDERSTAND WHY DEVELOPING COMMON ARCHITECTURES FOR ROBOT SYSTEMS IS CONSIDERED BY THE DEPARTMENT OF ENERGY TO BE SO IMPORTANT, I WOULD LIKE TO EXPLAIN THE **5-YEAR PLAN** IN A LITTLE GREATER DETAIL.

MOST PEOPLE DO NOT LOOK AT WASTE MANAGEMENT AS AN ATTRACTIVE TOPIC, BUT THE PROBLEMS CREATED BY THE GENERATION, TREATMENT, AND DISPOSAL OF WASTE ARE CONFOUNDING THIS NATION--WHETHER IN THE FORM OF A "BARGE WITHOUT A PORT," DISPOSABLE DIAPERS IN MUNICIPAL LANDFILLS, OR IN THE DISPOSAL OF HAZARDOUS INDUSTRIAL WASTES.

THE SIMPLE FACT IS THAT WASTE MANAGEMENT IS BOTTOM-LINE ECONOMICS, BOTTOM-LINE HEALTH PROTECTION. IN THE PAST WASTE MANAGEMENT WAS THOUGHT OF SIMPLY AS A SERVICE -- SOMEONE GENERATES WASTE AND SOME ELSE TAKES IT AWAY. ECONOMICS WAS NEVER A CONSIDERATION. TODAY, WE ARE ASKING, "WHAT IS THIS WASTE? HOW CAN WE STOP ITS GENERATION IN THE FIRST PLACE?" THAT IS SIGNIFICANT TO THE EVOLUTION OF WASTE MANAGEMENT.

OUR DEPARTMENTAL PLANNING METHODOLOGY RECOGNIZED THE DIFFICULTY IN HANDLING MIXED WASTE UNDER THE PRESENT-DAY RCRA REGULATORY FRAMEWORK AND ATTEMPTED TO IDENTIFY A NUMBER OF ACTIVITIES DESIGNED TO MEET THE SPIRIT AND INTENT OF THE ENVIRONMENTAL LAWS ENACTED BY CONGRESS AND BY STATE LEGISLATURES. D.O.E. HAS RESPONDED TO INCREASED AND JUSTIFIED PUBLIC SCRUTINY BY LIFTING THE "VEIL OF SECRECY" AND OPENING ITS DEFENSE FACILITIES TO STATE REGULATORS. THE DEPARTMENT IS UNDERWRITING A SIGNIFICANT PORTION OF THE COSTS ASSOCIATED WITH THE STATE MONITORING OF D.O.E.'S ENVIRONMENTAL COMPLIANCE. I BELIEVE THE DEPARTMENT OF ENERGY IS GOING TO PLAY A SIGNIFICANT ROLE IN FINDING SOLUTIONS TO MANY OF THE WASTE MANAGEMENT PROBLEMS THAT CONFOUND THIS NATION. WE HOPE TO BRING A NEW LEVEL OF UNDERSTANDING AND KNOWLEDGE TO THESE PROBLEMS. THROUGH D.O.E. INFORMATIONAL SEMINARS WE HAVE PROVIDED TECHNICAL DATA TO THE PUBLIC AND OTHERS LONG-CONSIDERED ADVERSARIAL TO D.O.E.'S WEAPONS PRODUCTION MISSION IN THE DEVELOPMENT OF ITS NEAR-TERM PLANS FOR ENVIRONMENTAL CLEANUP,

COMPLIANCE, AND WASTE MANAGEMENT. WE WELCOME THIS LONG-OVERDUE CHANGE AND VIEW IT AS A KEY ELEMENT TO REGAINING PUBLIC CONFIDENCE IN OUR ABILITY TO OPERATE THESE NUCLEAR FACILITIES SAFELY. IT IS ONLY WITH COMPLETE KNOWLEDGE AND ADEQUATE INFORMATION THAT WE CAN EXPECT THE PUBLIC TO SATISFACTORILY UNDERSTAND THE PROBLEMS, OR RISKS, THAT FACE OUR NATION. BUT WE CAN'T DO IT ALONE. WE ALSO NEED YOU -- THE SCIENTISTS AND TECHNOLOGISTS -- TO HELP US APPLY NEW AND INNOVATIVE TECHNOLOGIES TO THESE PROBLEMS.

THE DEPARTMENT'S **WASTE MANAGEMENT PROGRAM** IS BEST CHARACTERIZED IN ITS **5-YEAR PLAN** AND, PARTICULARLY, THE R&D CHAPTER OF THE PLAN. JUST LAST MARCH THE SECRETARY PROMISED CONGRESS THAT HE WOULD DELIVER A COMPREHENSIVE PLAN OUTLINING SPECIFIC ACTIONS D.O.E. INTENDS TO UNDERTAKE OVER THE NEXT 5 YEARS TO ACHIEVE COMPLIANCE WITH FEDERAL ENVIRONMENTAL LAWS AND TO BEGIN TO CLEAN UP AND RESTORE THOSE SITES THAT WE HAVE CONTAMINATED OVER THE PAST 40 YEARS.

PUBLISHED LAST AUGUST, THE DEPARTMENT'S **ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT 5-YEAR PLAN** CONTAINS THE FRAMEWORK FOR D.O.E. TO CHARACTERIZE, PRIORITIZE, AND CONSOLIDATE CLEANUP ACTIVITIES AT EVERY SITE. IMMEDIATE PROBLEMS WILL BE CONFINED AND CORRECTED. THE PRIORITIES OF A 30-YEAR CLEANUP EFFORT WILL BE BASED ON CREDIBLE SCIENCE AND TECHNOLOGY AND, HOPEFULLY, ON NEW NATIONAL STANDARDS THAT FINALLY RESOLVE THE DILEMMA WE FACE TODAY REGARDING "HOW CLEAN IS CLEAN?" WE ARE ALREADY HARD AT WORK WITH

STATES AND E.P.A. WE BELIEVE THIS PROCESS WILL HELP TO RE-ESTABLISH D.O.E'S CREDIBILITY WITH CONGRESS, THE AMERICAN PUBLIC, AND REGULATORY BODIES AT BOTH THE FEDERAL AND STATE LEVELS.

D.O.E. RECENTLY RELEASED A SEPARATE CHAPTER TO THE **5-YEAR PLAN** FOR **RESEARCH, DEVELOPMENT, DEMONSTRATION, TESTING AND EVALUATION ACTIVITIES.** THE R&D PLAN ILLUSTRATES A REAL EFFORT TO GET RESULTS FROM RESEARCH AND TECHNOLOGY DEMONSTRATIONS WITHIN A TIMETABLE THAT IS DRIVEN BY A "HARD" ASSESSMENT OF NEED AND RISK. BY THE TERM "NEED-DRIVEN," I MEAN THAT THE BASIC NEED IS TO SOLVE A PROBLEM, NOT **RELOCATE** IT. WE MUST KNOW HOW WE CAN SEGREGATE, SEPARATE, AND ISOLATE HAZARDOUS COMPONENTS. DECISIONS WILL BE MADE ON THE BASIS OF PERFORMANCE AND RETURN ON EACH DOLLAR SPENT. THE SCIENTIFIC/ INDUSTRIAL COMMUNITY IS CERTAINLY CAPABLE OF IDENTIFYING THESE KINDS OF RETURNS, AND WE WILL BUILD A METHODOLOGY THAT APPLIES TOUGH COST/BENEFIT CRITERIA TO ALL WASTE-RELATED R&D. WE HAVE THE CAPABILITY TO INCORPORATE INDUSTRY AND PEER ACADEMIC INPUT TO DETERMINE WHAT IS REALLY USEFUL AND ACHIEVABLE, SO WE WILL NOT WASTE TIME ON EVALUATING COMPETING PROPOSALS THAT HAVE LIMITED VALUE.

I BELIEVE D.O.E.'S **5-YEAR PLAN** AND ITS RESEARCH COMPONENT -- AND THE SITE IMPLEMENTATION PLANS THAT ARE BEING PREPARED NOW BY EACH MAJOR D.O.E. FIELD OFFICE -- WILL PROVIDE THE INITIAL STEPS TOWARD CREDIBILITY. PERFORMANCE WILL BE THE ULTIMATE MEASUREMENT. D.O.E. IS GOING OUT OF ITS WAY TO SOLICIT AND INCORPORATE THE

VIEWS OF OUTSIDE GROUPS STATE AND TRIBAL OFFICIALS, E.P.A., AND THE NATIONAL ACADEMY OF SCIENCE. WE ARE WEIGHING THE MERITS OF EXPANDING THIS GROUP FURTHER TO BETTER ASSURE CONSENSUS. THIS REMARKABLE CHANGE WILL HELP FOCUS ATTENTION AND FUNDS TOWARD FINALLY SOLVING THE MANY ENVIRONMENTAL CLEANUP AND WASTE MANAGEMENT PROBLEMS WE CURRENTLY FACE, BOTH IN THIS COUNTRY AND ABROAD.

THE DEPARTMENT OF ENERGY MUST APPLY ROBOTICS TO SEVERAL MAJOR CLEANUP ACTIVITIES IDENTIFIED IN OUR **5-YEAR PLAN.** THESE ACTIVITIES INCLUDE (BUT ARE NOT LIMITED TO):

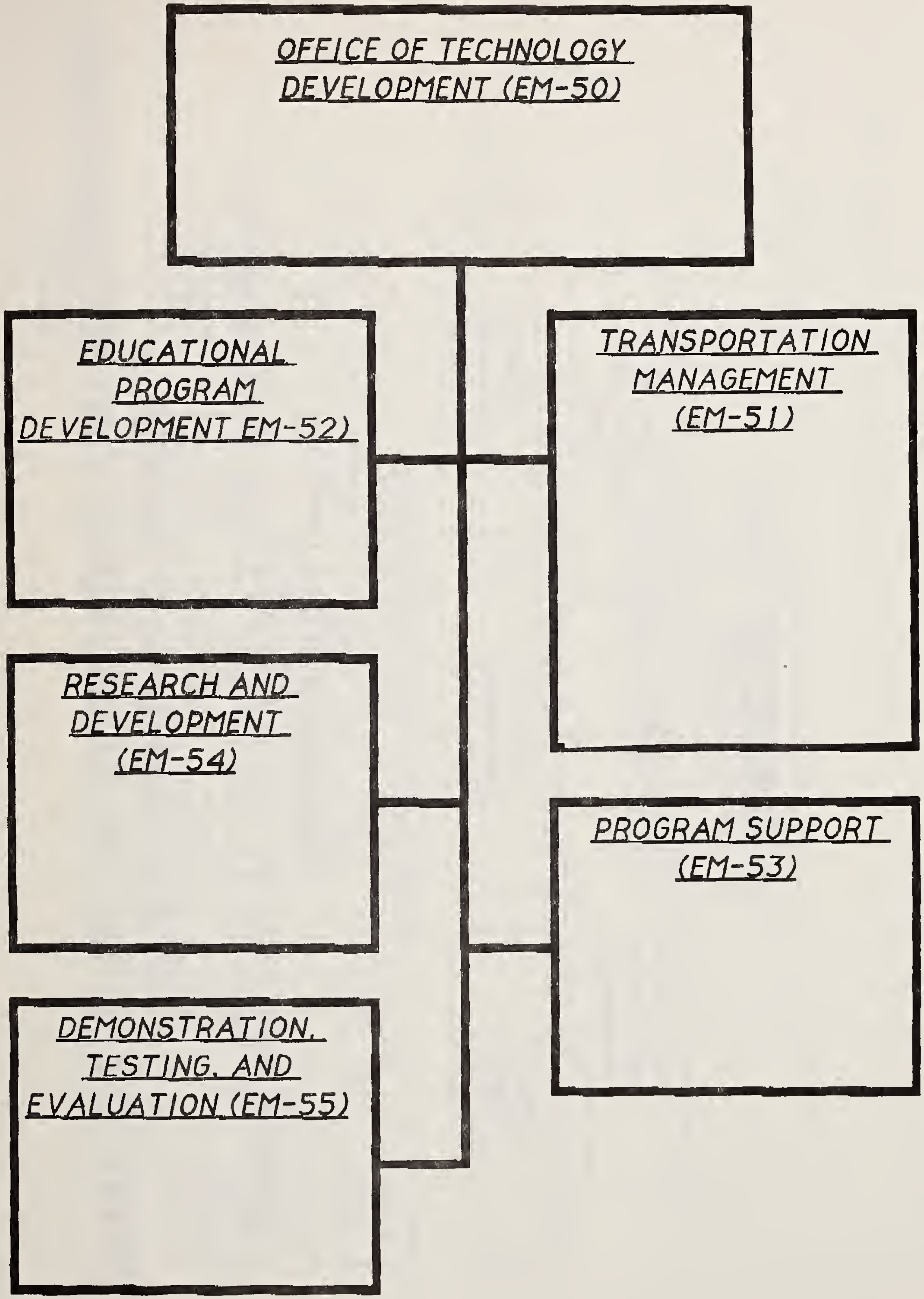
- SAMPLING OF "HOT" SITES;
- SAMPLING AND RETRIEVAL OF SINGLE-SHELL TANKS;
- SITE CHARACTERIZATIONS;
- DECOMMISSIONING AND DECONTAMINATION;
- PROCESSING AND FUTURE PROCESSING;
- LARGE MACHINE ROBOTICS FOR RETRIEVAL;
- AUTOMATED SYSTEMS FOR PRODUCTION WASTE MINIMIZATION.

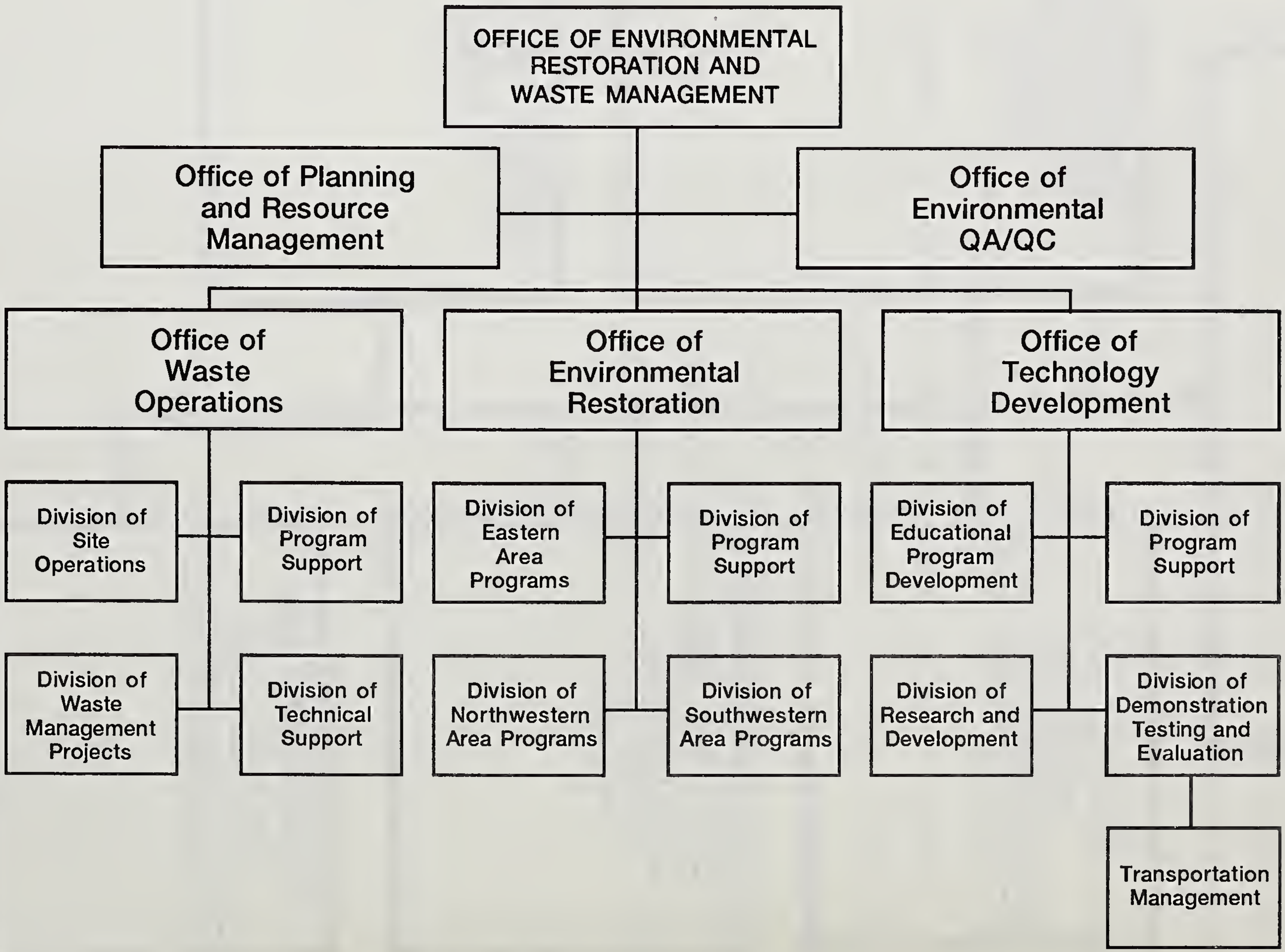
ALL OF US WILL HEAR OVER THE NEXT TWO DAYS WHAT METHODOLOGIES ARE BEING USED AT D.O.E. SITES FOR DEVELOPMENT AND MAINTENANCE OF SOFTWARE RELATED TO ROBOTIC AND REMOTE SYSTEMS. WE WILL ALSO HEAR FROM REPRESENTATIVES OF THE GOVERNMENT AGENCIES INVOLVED IN DEVELOPING COMMON ARCHITECTURES FOR REMOTE SYSTEMS.

ABOVE ALL, WE WANT THIS WORKSHOP TO YIELD A CLEAR DIRECTION OF HOW D.O.E. AND THE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (N.I.S.T.) WILL WORK TOGETHER TO **DEVELOP METHODOLOGIES** SO THAT D.O.E. CAN DETERMINE AND DEFINE ITS REQUIREMENTS AND, EVENTUALLY, ITS ROBOTIC STANDARDS. WE HOPE TO SPEND OUR TIME TOGETHER LISTENING TO TECHNOLOGISTS AND OTHER PROGRAM PARTICIPANTS DESCRIBE THE IMPORTANCE OF ROBOTICS TO THE **ENVIRONMENTAL RESTORATION/WASTE MANAGEMENT PLAN** AND HOW N.I.S.T. INTENDS TO DELINEATE THE METHODOLOGIES REQUIRED BY D.O.E. IN DEVELOPING STANDARDS. IF THIS TASK WERE ONE WHICH COULD BE ACCOMPLISHED WITHOUT YOU, WE WOULD NOT BE HERE TODAY. YOUR CONTRIBUTIONS ARE VITAL TO THE SUCCESS OF THIS WORKSHOP AND TO THIS MISSION; NAMELY, THE DEVELOPMENT OF SENSIBLE, SCIENTIFICALLY SOUND, AND EFFICIENT METHODOLOGIES.

LET'S GET TO WORK.

THANK YOU


OFFICE OF TECHNOLOGY DEVELOPMENT (EM-50)
EDUCATIONAL PROGRAM DEVELOPMENT EM-52)
TRANSPORTATION MANAGEMENT (EM-51)
RESEARCH AND DEVELOPMENT (EM-54)
PROGRAM SUPPORT (EM-53)
DEMONSTRATION, TESTING, AND EVALUATION (EM-55)


OFFICE OF ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT
Office of Planning and Resource Management
Office of Environmental QA/QC
Office of Waste Operations
Office of Environmental Restoration
Office of Technology Development
Division of Site Operations
Division of Program Support
Division of Waste Management Projects
Division of Technical Support
Division of Eastern Area Programs
Division of Program Support
Division of Northwestern Area Programs
Division of Southwestern Area Programs
Division of Educational Program Development
Division of Program Support
Division of Research and Development
Division of Demonstration Testing and Evaluation
Transportation Management

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
DEPARTMENT OF ENERGY

ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT

ROBOTICS MEETING

STEVEN COWAN

JANUARY 30, 1990

THE DEPARTMENT ISSUED THE FIVE YEAR PLAN FOR

ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT IN

AUGUST 1989

- IT ESTABLISHED THE BASELINE APPROACH TO MEET THE 30-YEAR COMMITMENT FOR COMPLIANCE AND CLEANUP

- IT RECOGNIZED THAT AN AGGRESSIVE R&D PROGRAM WAS NEEDED TO ENABLE THE DEPARTMENT TO MEET THIS COMMITMENT (FASTER, CHEAPER, BETTER)

- DRAFT APPLIED RESEARCH, DEVELOPMENT, DEMONSTRATION, TESTING, AND EVALUATION PLAN ISSUED IN NOVEMBER 1989

SECRETARY WATKINS ESTABLISHED THE OFFICE OF ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT IN NOVEMBER 1989

- CENTRALIZES MANAGEMENT ACTIVITIES UNDER ONE OFFICE

- EMPHASIZES SIGNIFICANCE OF ENVIRONMENTAL OBJECTIVES IN MEETING DEPARTMENT'S DEFENSE AND ENERGY SECURITY MISSION

THE OFFICE OF TECHNOLOGY DEVELOPMENT WILL SUPPORT THE OPERATIONAL REQUIREMENTS OF ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT

- FOR ENVIRONMENTAL RESTORATION, NEAR-TERM EMPHASIS ON CONTAINMENT AND CHARACTERIZATION

- FOR WASTE MANAGEMENT, EMPHASIS WILL BE ON MINIMIZATION/AVOIDANCE AND TREATMENT, STORAGE AND DISPOSAL

THE DEPARTMENT WELCOMES NIST ASSISTANCE

IN ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT EFFORTS;

PARTICULARLY WITH THE DEVELOPMENT AND APPLICATION OF

ROBOTICS TECHNOLOGY

- APPLICATIONS EXPECTED TO MINIMIZE WORKER EXPOSURE AND INCREASE HANDLING PRODUCTIVITY

- WIDE RANGE OF APPLICATION FOR WASTE OPERATIONS, INCLUDING SAMPLING; REMEDIATION AND DECONTAMINATION/DECOMMISSIONING

ENVIRONMENTAL RESTORATION & WASTE MANAGEMENT'S NATIONAL ROBOTICS TECHNOLOGY DEVELOPMENT PROGRAM

"AN OVERVIEW AT THE START"

S. A. MEACHAM
OAK RIDGE NATIONAL LABORATORY

P. J. EICKER
SANDIA NATIONAL LABORATORIES

DOE/NIST WORKSHOP ON
COMMON ARCHITECTURES FOR ROBOTIC SYSTEMS

JANUARY 30, 1990

THE OFFICE OF TECHNOLOGY DEVELOPMENT HAS ESTABLISHED THE "NATIONAL ROBOTICS TECHNOLOGY DEVELOPMENT PROGRAM (NRTDP)" TO:

- Integrate Robotic RDDT&E Activities on a National Basis.
- Provide Need-Oriented, Timely, and Economical Robotics Technology to Support Environmental and Waste Operations Activities at the DOE Sites.

THE NRTDP WILL:

- Be a Need-Based Program Directed at Supporting ER&WM Activities at DOE Sites.

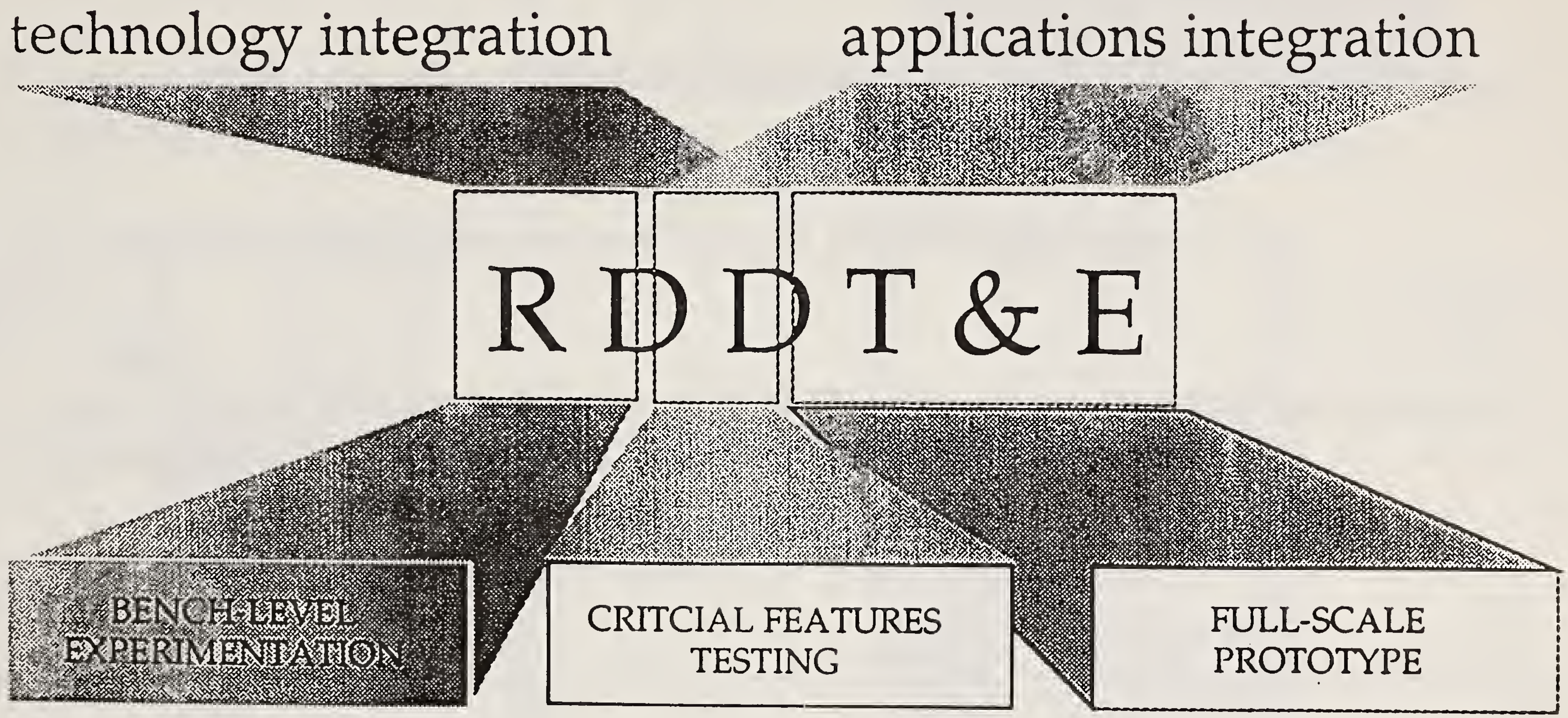
- Require Input From the Site Users (Both Project and Technologist) at the Earliest Stages of the Planning Process.

- Develop a Road Map that Provides the OTD with an Overall Assessment, Integrates the Whole, and Supports the Deployment and Use of Robotics at the DOE Sites.

THE OBJECTIVES OF THE NRTDP ARE TO DEVELOP, TEST, AND MAKE AVAILABLE ROBOTIC TECHNOLOGIES WHICH ARE:

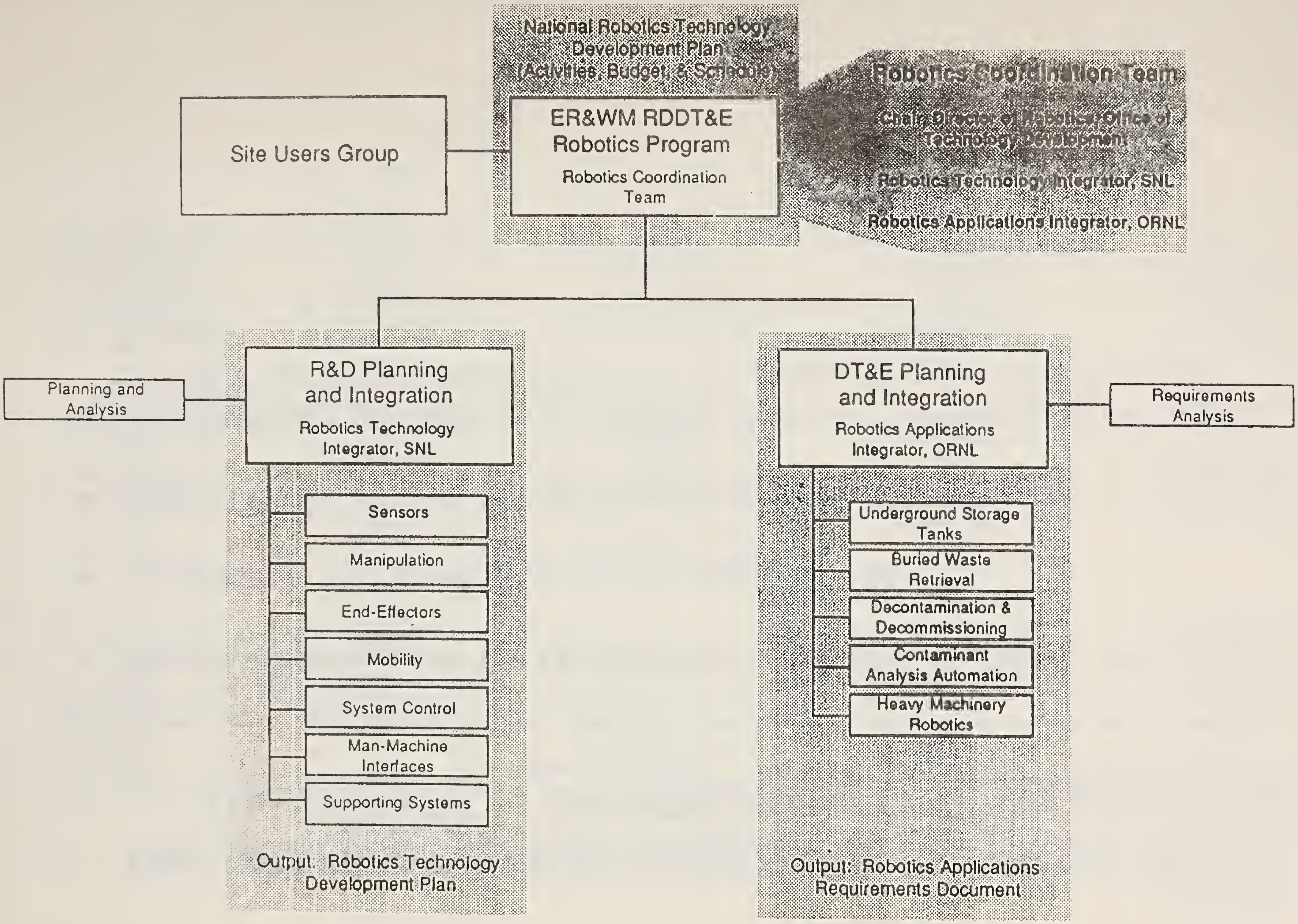
- Faster - Increase the Speed and Productivity with Which ER&WM Operations Can be Carried Out.
- Better - Increase the Safety of ER&WM Operations.
- Cheaper - Lower the Life Cycle Costs.

ER&WM ROBOTICS PROGRAM



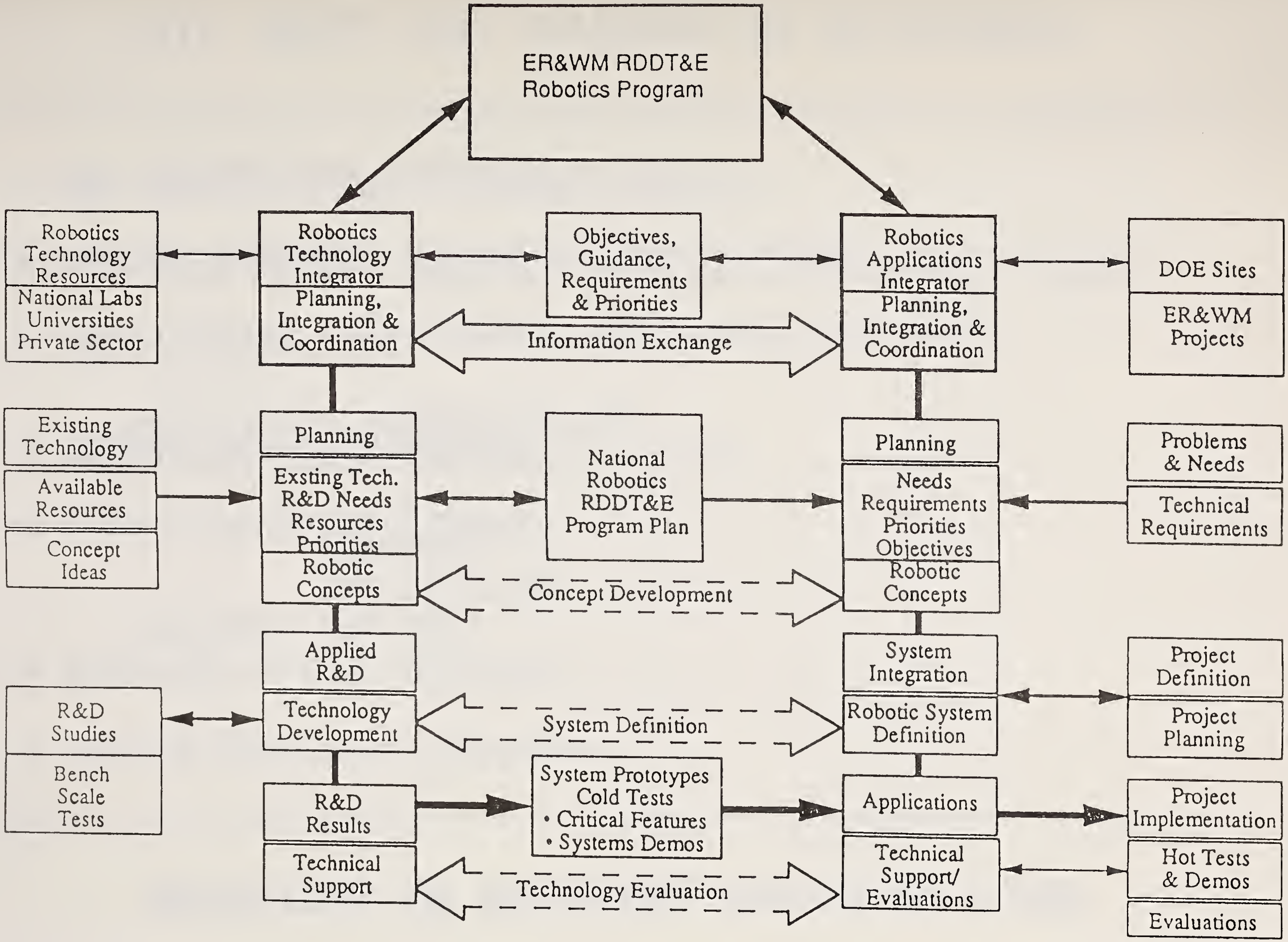
THE INTEGRATORS ARE JOINTLY RESPONSIBLE FOR INTERFACING AND INTEGRATING THE ACTIVITIES IN TWO AREAS -- TECHNOLOGY AND APPLICATIONS

- The Robotics Technology Integrator is Responsible For:
  - Coordinating the Research and Development Activities.
  - The Preparation and Annual Updating of the Technology Development Plan.
- The Robotics Applications Integrator is Responsible For:
  - Coordinating the Demonstration, Test, and Evaluation Activities.
  - The Preparation and Annual Updating of the Requirements Document.


National Robotics Technology Development Plan (Activities, Budget, & Schedule)
Site Users Group
ER&WM RDDT&E Robotics Program
Robotics Coordination Team
Robotics Coordination Team
Chair: Director of Robotics Office of Technology Development
Robotics Technology Integrator, SNL
Robotics Applications Integrator, ORNL
Planning and Analysis
R&D Planning and Integration
Robotics Technology Integrator, SNL
Sensors
Manipulation
End-Effectors
Mobility
System Control
Man-Machine Interfaces
Supporting Systems
Output: Robotics Technology Development Plan
DT&E Planning and Integration
Robotics Applications Integrator, ORNL
Requirements Analysis
Underground Storage Tanks
Buried Waste Retrieval
Decontamination & Decommissioning
Contaminant Analysis Automation
Heavy Machinery Robotics
Output: Robotics Applications Requirements Document

THE ROBOTICS USERS COMMITTEE, CHAIRED BY THE DIRECTOR OF ROBOTICS, OTD, WILL:

- Provide Information for the Development of the National Plan.
- Participate in the Development of the National Plan.
- Be the Formal Contact Between the Program and the Projects.
- Provide Recommendations for Potential Robotics Technology Applications to Assist the Coordination Team in Formulating Program Guidance and Direction.


ER&WM RDDT&E
Robotics Program
Robotics Technology Resources
National Labs Universities Private Sector
Robotics Technology Integrator
Planning, Integration & Coordination
Objectives, Guidance, Requirements & Priorities
Information Exchange
Robotics Applications Integrator
Planning, Integration & Coordination
DOE Sites
ER&WM Projects
Existing Technology
Available Resources
Concept Ideas
Planning
Exsting Tech. R&D Needs Resources Priorities
Robotic Concepts
National Robotics RDDT&E Program Plan
Planning
Needs Requirements Priorities Objectives
Robotic Concepts
Problems & Needs
Technical Requirements
Concept Development
Applied R&D
Technology Development
R&D Studies
Bench Scale Tests
System Definition
System Integration
Robotic System Definition
Project Definition
Project Planning
R&D Results
System Prototypes Cold Tests
• Critical Features
• Systems Demos
Applications
Project Implementation
Technical Support
Technology Evaluation
Technical Support/ Evaluations
Hot Tests & Demos
Evaluations

INITIATION OF NATIONAL PROGRAM PLAN

- Establish High Priority Applications.
- Workshops for Each Application.
  Attendees: Site Users
Site Roboticists
ORNL/SNL
- Identify High Priority Site-Specific Problems
  Which can be Impacted by Plan.
- Identify Generic Technologies for High Priority Applications.
- Establish Application, Technology, Time Crosscuts.

This Provides Basic Ingredients for Plan.

SITE VISITS ARE PLANNED TO DETERMINE:

- The Highest Priorities in ER&WM Operations.
- Each Major Activity's Objectives, Approach, and Associated Hazards.
- The Schedule Drivers.
- Potential Robotic Applications.
- Current Development Activities.

Savannah River Site Robotics

Robots

Zymate *vial filling*
Zymate *radiation counter*
Hudson *radiation counter*
Unimate *press lubrication*
Cincinnati Milacron *die lubrication*
GCA (Cimcorp)
- jointed arm *Californium waste removal* (saved 35 rem first year)
- jointed arm *demonstration*
- jointed arm *radioactive sample handling*
- gantry with jointed arm *TRU waste handling development* (8 DOF)

Nikko gantry *Plutonium handling development*
SRS designed *reactor tank remote ultrasonic inspection* (68000 on VME bus)
ALVIN *mobile robot development*
SIMON *mobile robot for remote radiation, temp. and video monitoring* (Z80 on STD bus, C)

Mobile Teleoperators

Pedsco *waste tank top survey*
21st Century WASP *waste tank top concrete scabbling decon* (radio controlled)
21st Century WASP *remove lead from 10 reactor resin vessels* (up to 5 Rem/hr.)
Pedsco *steam decon canyon corridor*
Pedsco *remove junction box* (200 Rem/hr.)
OAO 800 *assembly retrieval in reactor*
ACEC *modified for radio control* (8088 on STD bus, Forth)
modular arm *modular maintenance demonstration*
Radio controlled Bobcat front end loader
Radio controlled Pedsco
ARD Super Scavenger*underwater cleaning*
SRS designed Remote Overhead Video Extendable Robot (50 ft. reach cameras on moble base)
pipe crawlers

Miscellaneous

remote radiation detectors with radio link “mission modules” (Z80, Forth)
SRS designed remote microwave portable camera systems
SRS designed portable monitor/recorder/camera control systems
McDonnel Douglas wireframe robot computer simulation system
on order; IGRIP solid modeling robot computer simulation system

DOE/SAN

- Primary R&D facilities
  - SLAC, SNLL, LBL, LLNL, etc.

- Emphasis:
  - High energy physics research
  - Nuclear weapons R&D
  - Energy research
  - Laser applications

- Limited robotics involvement
  - Automated parts machining
  - Special Isotope Separation (SIS) Plant Pu handling applications

SIS robotics applications

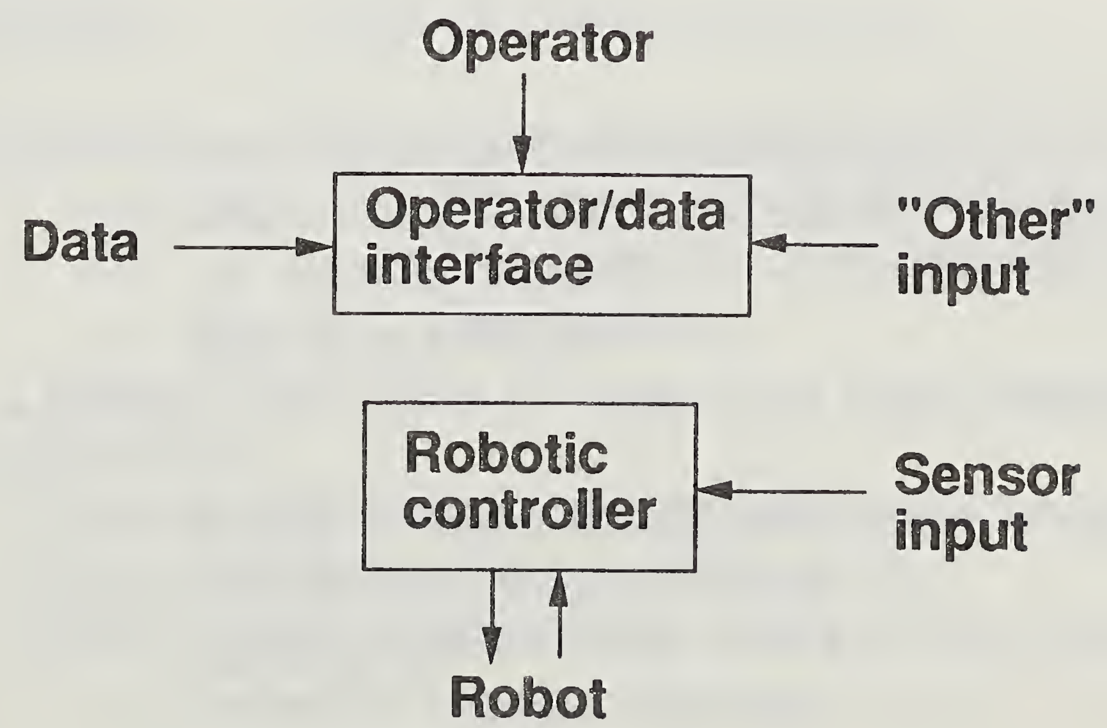
- **Motivation:** Worker dose reduction
- **Application:** Pu and component handling in gloveboxes
  - Separator parts servicing
  - Pu processing equipment servicing
  - Pu transfers
- **Complications**
  - Adverse glovebox environment
  - High reliability/safety requirements
  - Wide variety of infrequent and complex operations

SIS robotics status

- Early 7 axis robot evaluation
  - Interphase robot
  - Delta tan control system
  - FORTRAN program ming
  - Coordinate teach system
  - No interactive sensor/operator control

- Application work for IBM ECR robot starting up
  - IMB ALPS system
  - "C" programming
  - Data bus interface to balance of system
  - Interactive sensor integration

Simplified control architecture



Software/control system architecture preferences

- Utilize a variety of communications systems
  - Recognizes differences in commercial systems
- Flexible user interface
  - Sensory inputs
  - Interactive operator control
- Effective "accident" avoidance
- Moderate task speed
- Easily adapted to a wide variety of tasks

RICHLAND OPERATIONS

ROBOTICS / AUTOMATION
LESSONS LEARNED

ANY NEW OPERATING SYSTEM OR STANDARD ARCHITECTURE MUST BE TEMPERED WITH EXISTING INDUSTRIALLY AVAILABLE TECHNOLOGY

SYSTEM REQUIREMENTS WITHIN THE NUCLEAR ENVIRONMENT ARE QUITE DIFFERENT THAN ON THE FACTORY FLOOR

- HIGHLY UNSTRUCTURED ENVIRONMENT
- UNIQUE ENVIRONMENTAL EONDITIONS
- SYSTEMS MUST BE MODULAR & DISPOSABLE

MOST PROJECTS HAVE INVOLVED SYNCHRONOUS PROCESSES

NEW STANDARDS MUST NOT RESTRICT FLEXIBILITY OR IMPOSE NEW CONSTRAINTS ON EXISTING PROJECTS

RICHLAND OPERATIONS

PACIFIC NORTHWEST LABS

ROBOTICS / AUTOMATION
PROJECT EXAMPLE

PROTOTYPE AUTOMATED REFUELING SYSTEM (PARS):

- SPONSOR: WESTINGHOUSE HANFORD CO.
- WROTE SPECS. IN COOPERATION WITH SPONSOR
- MAINTAINED CLOSE CONTACT WITH ROBOT VENDOR
- DEVELOPED STATE-OF-THE-ART END EFFECTOR
- DEVELOPED OVERALL CONTROL SYSTEM WITH CONTROLLER AN INTEGRAL PART
- DREW UPON SAVANNAH RIVER LABS. EXPERIENCE WITH SIMILAR EQUIPMENT

OUTCOME:

COMPLETE DESIGN AND DEVELOPMENT THROUGH HARDWARE PHASE OF PROJECT - ROBOT & CONTROL SYSTEM DELIVERED

RICHLAND OPERATIONS

ROBOTICS / AUTOMATION

HARDWARE ARCHITECTURES:

VARIED ARCHITECTURES BASED UPON:

- CUSTOMER NEEDS
- COMMERCIAL EQUIPMENT AVAILABILITY
- SYSTEM COMPLEXITY
- EXPERIENCE

MOST SYSTEMS ARE PC/AT 80386 BASED

- SIMPLE ARCHITECTURE
- CUSTOMER FAMILIARITY
- AVAILABILITY OF GOOD DEVELOPMENT ENVIRONMENTS
- MOST SYSTEMS DON'T REQUIRE ANY GREATER SOPHISTICATION

VME, VXI & MULTIBUS SYSTEMS ALSO USED

RICHLAND OPERATIONS

ROBOTICS / AUTOMATION

SOFTWARE DESIGN METHODOLOGY:

STRUCTURED ANALYSIS & DESIGN OF REAL-TIME CONTROL SYSTEMS (YOURDON, OTHERS)

RICHLAND OPERATIONS

PACIFIC NORTHWEST LABS

ROBOTICS / AUTOMATION
SYSTEM DESIGN APPROACH

ASSESSMENT OF CURRENT TECHNOLOGY

- CAN IT BE DONE WITH AVAILABLE TECHNOLOGY?
- PROOF-OF-PRINCIPLE INVESTIGATION
- TECHNICAL RISK ASSESSMENT / DECISION POINT

CONCEPTUAL DESIGN

- SYSTEM SPECIFICATIONS
- ECONOMIC JUSTIFICATION

DETAIL DESIGN & FABRICATION

RICHLAND OPERATIONS

PACIFIC NORTHWEST LABS

ROBOTICS / AUTOMATION PROJECTS

- ROBOTIC MANNEQUIN
- PROTOTYPE AUTOMATED REFUELING SYSTEM (WHC)
- SST IN-TANK INSPECTION SYSTEM (WHC)

- O-RING INSPECTION SYSTEM
- PRINTED CIRCUIT BOARD REPAIR SYSTEM
- ROBOTIC PART INSPECTION / REVERSE ENGINEERING

- ANALYTICAL CHEMISTRY LABORATORY AUTOMATION
- VARIOUS CLASSIFIED PROJECTS

RICHLAND OPERATIONS

HANFORD NUCLEAR RESERVATION

SITE OPERATIONS:
WESTINGHOUSE HANFORD CO.

PACIFIC NORTHWEST LABORATORIES:
BATTELLE MEMORIAL INSTITUTE

Oak Ridge National Laboratory Robotic Control Architectures

William. R. Hamel
Telerobotic Systems Section

Workshop on Common Architectures for Robotic Systems
National Institute of Standards & Technology
Gaithersburg, Maryland
January 30-31, 1990

OUTLINE:

- Characteristics
- Examples of Systems Developed
- Experiences and Views regarding Standardization Issues

ROBOTICS-RELATED ACTIVITIES:

- Remote Manipulation
- Mobile Systems
- Distributed Digital Controls
  - multi-microprocessing
  - commerical RT operating systems
  - FORTH, C, FORTRAN
  - high speed data links
  - Standard bus designs, 16 & 32 bit
- Evolutionary approach to hardware and software architectures

EXAMPLES:

- CRL Model M2
- Advanced Integrated Maintenance System
- NASA Laboratory Telerobotic Manipulator
- HERMIES III Research Robot
- Soldier Robot Interface Project

M2 Servomanipulator Architecture

- M2 was the first digital servomanipulator constructed at ORNL.
- Design based on a converted CRL anolog control manipulator.
- MS controls: distributed architecture with 32 Intel 8031s in four arm control racks.
- All joint code: assembly language and in ROM.
- Operator interface is menu driven (Z80, CPM, S100 system in Basic.)
- Software difficult since joint code is in firmware and S100 is at the maximum size.

AIMS Controls Description

- Advanced Integrated Maintenance System: seven separate racks -- Man-machine Interface (MMI), Auxillary Control System (ACS), two master arm racks, two slave arm racks, and a transporter rack.

- Hardware: utilized a total of 15 Motorola 68000 SBCs in Multibus I backplanes running PolyFORTH.

- MMI, ACS, and the two master racks connected through a fiber optic local area network; master-to-slave links are dedicated fiber optic.

- The "in-cell" slave racks and the transporter use ROMed FORTH.

- MMI, ACS, and master rack code utilized FORTH application code loaded off of the system hard disk on top of a ROMed FORTH kernel.

- Software based on a modular hierarchical approach.

- Software modified for development and experimentation.

NASA-LTM Controls Architecture

- Hardware: two VME systems with three 68020 SBCs (each for arm control algorithms), 12 joint processors based on the Intel 80C197 for sensor data acquisition, and a Mac II for operator interface.
- OS9: a modular, multiprogramming, multilingual, and multitasking system for the 68000 processor family.
- OS9 uses a hierarchical file structure with an assembly language kernel for real-time speed and is ROMable.
- All application code is written in C, including control algorithms.
- Forth firmware used for the joint processors (transparent to user).
- Software: modular hierarchical approach similar to ASM and M2.

Hermies III Architecture

- Hermies III: testbed for research and development in vision, robotic arm control, path planning, and navigation.
- Hardware: four VME racks with five 68020 based SBCs and a four node Ncube parallel processor research.
- The operating system is OS9 with an eventual interface to UNIX; all application code is written in C.
- Software controlled by programming specifications and data flow requirements.
- Hardware specific code isolated from application code through software library approach.

Soldier Robot Interface Program (SRIP) Architecture

- The SRIP is a remote driving and robotics platform for Integrated vehicle and manipulator controls development for the U.S. Army's Human Engineering Laboratory (HEL).

- The SRIP wheeled vehicle uses VME racks, Motorola 68020 SBCs, and OS9 with application code in C.

- Current software is based on past ORNL hierarchical implementations.

- Plans have been made to rewrite software to make it compatible with the RCS approach for the Technology Enhancement for Autonomous Machines (TEAM) program, another HEL remote driving R&D effort currently in its early stages.

CHALLENGES FOR ARCHITECTURAL STANDARDIZATION:

- Provide a sound methodology which can track hardware developments
- Provide designer freedom–and yet be all things to all people
- Cost effective standardization in a competitive procurement environment

Architectures: Intent and Scope = Essence

Stanrdards should provide:

- Methodologies, software, and hardware
- Software development tools: Equipment, automation/diagnostics, documentation, team programmers

Software Side: "Rules" for

- Spatial - temporal decomposition ➡ Modularity
- Communications ➡ Connectivity
- HMI ➡ Flexibility

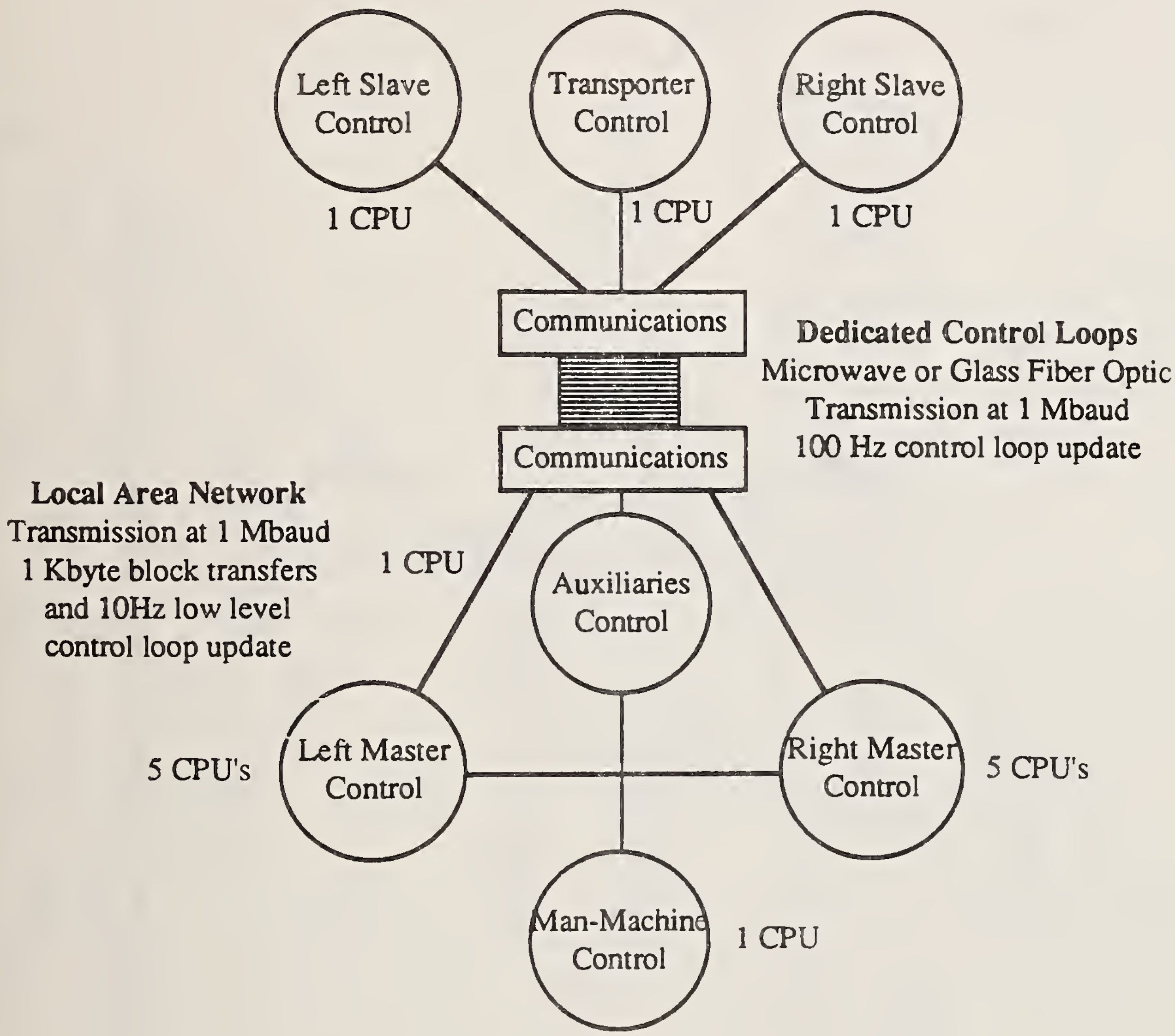
EXPERIENCES:

- Architectures are like personalities
- Typical systems are massive investments
- Architectures are a function of both hardware and software
- System performance requirements push technology
- RT embedded systems require hardware and software synergy

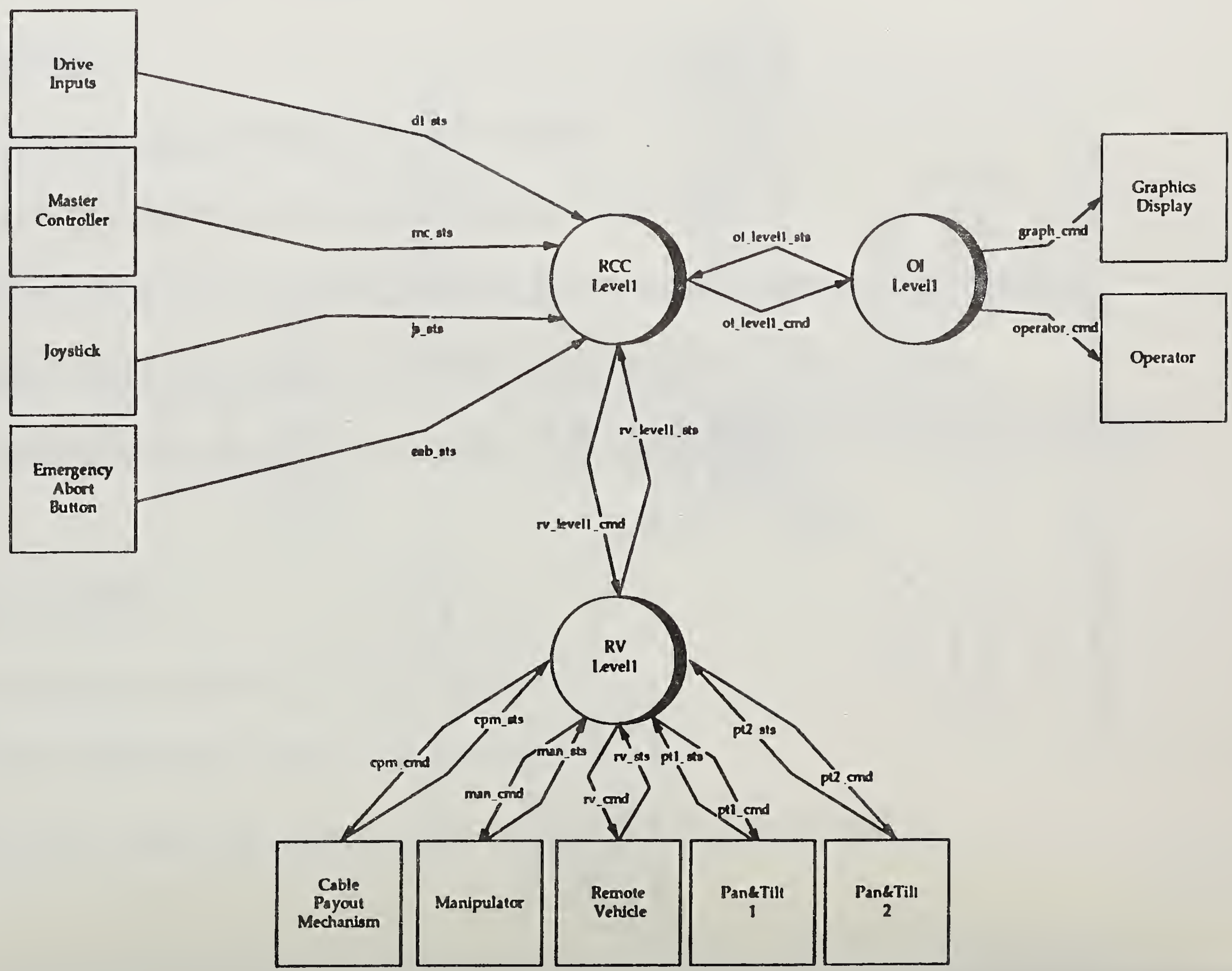
OBSERVATIONS:

- Processors change every 1-2 years
- Busses change every 2-3 years
- Even the best software lags hardware significantly

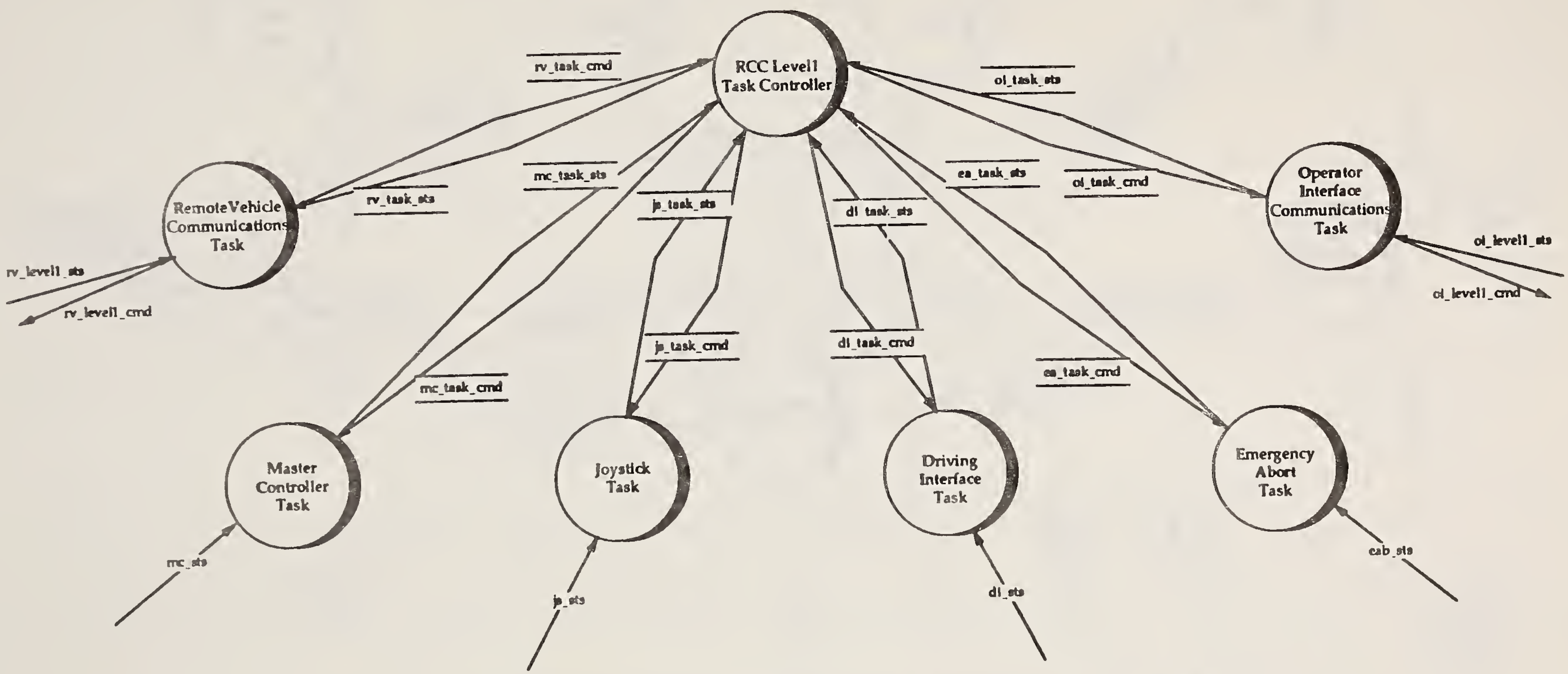
Advanced Integrated Maintenance System



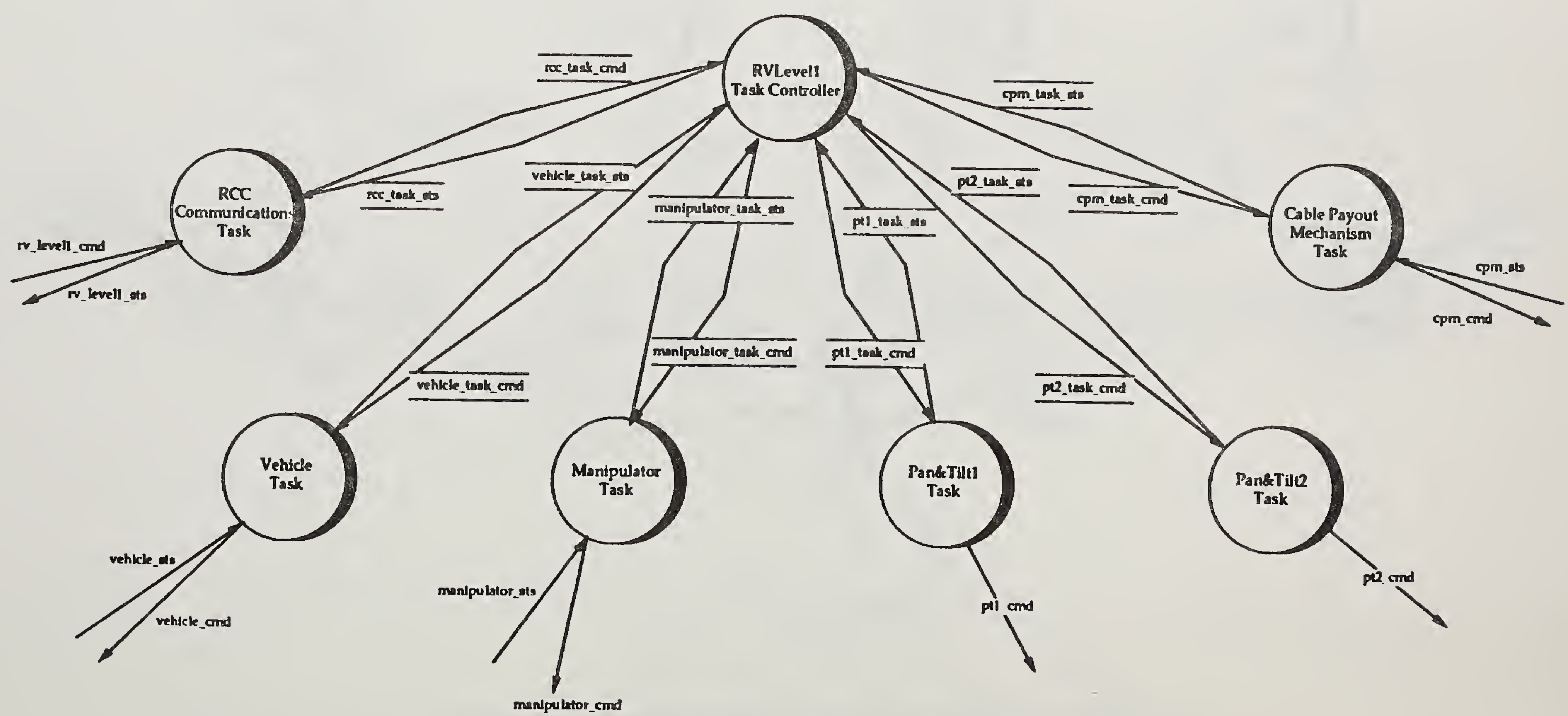
SRIP Context Diagram



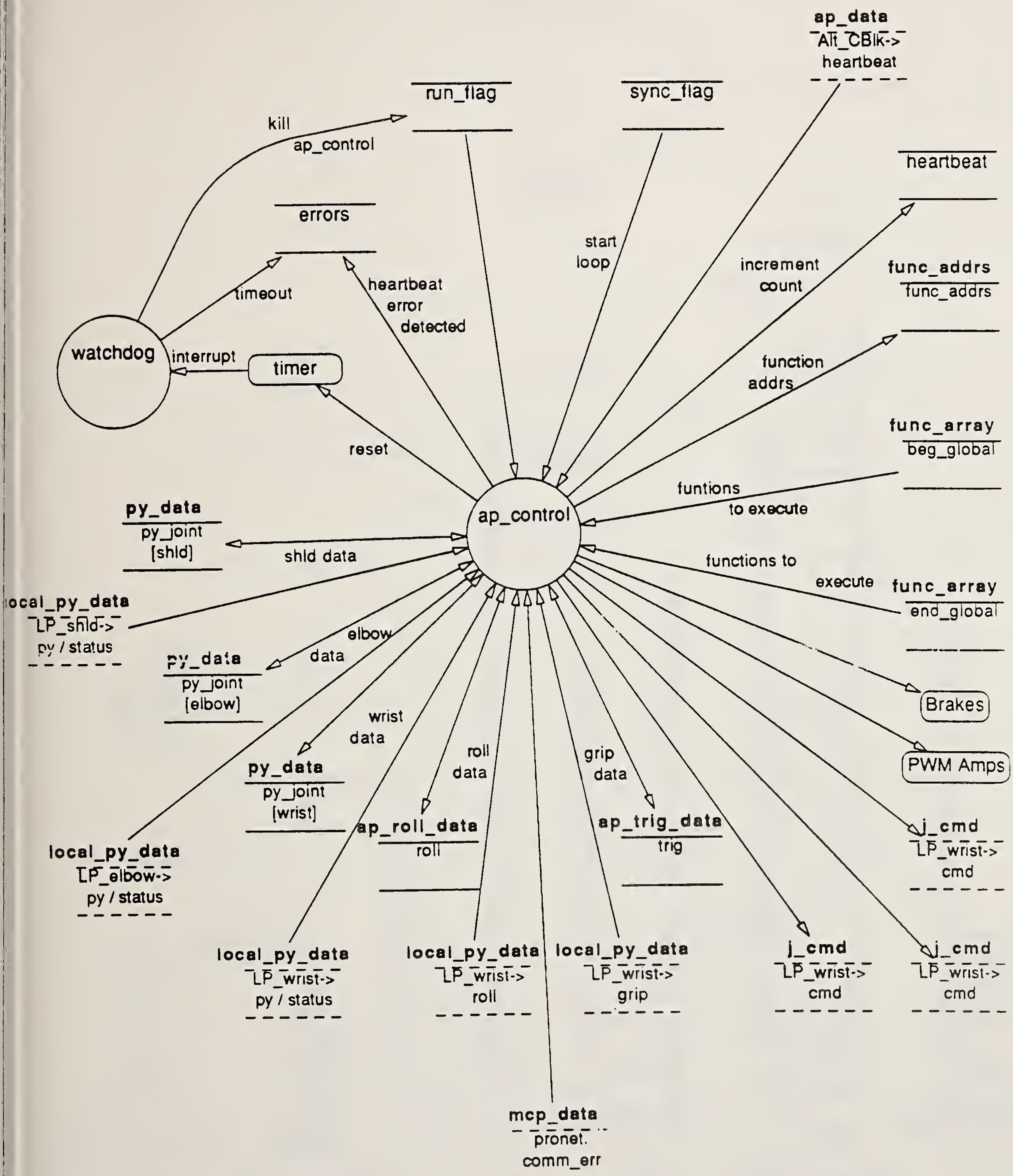
Remote Control Center (RCC) Level1



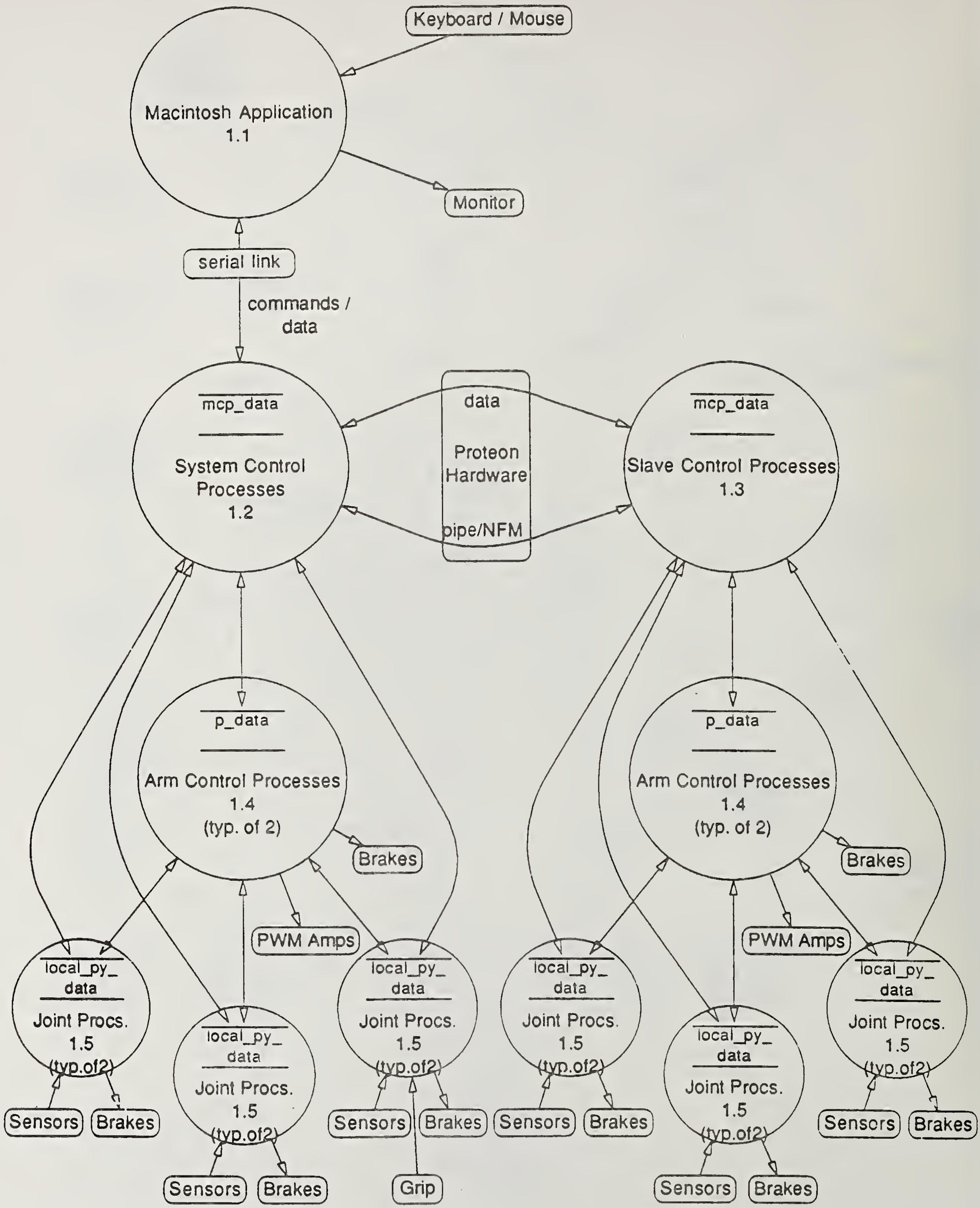
Remote Vehicle (RV) Level1



1.4 ARM CONTROL PROCESSES



1.0 LTM SYSTEM (Hardware Level)



INEL
WINCO

I. Activities

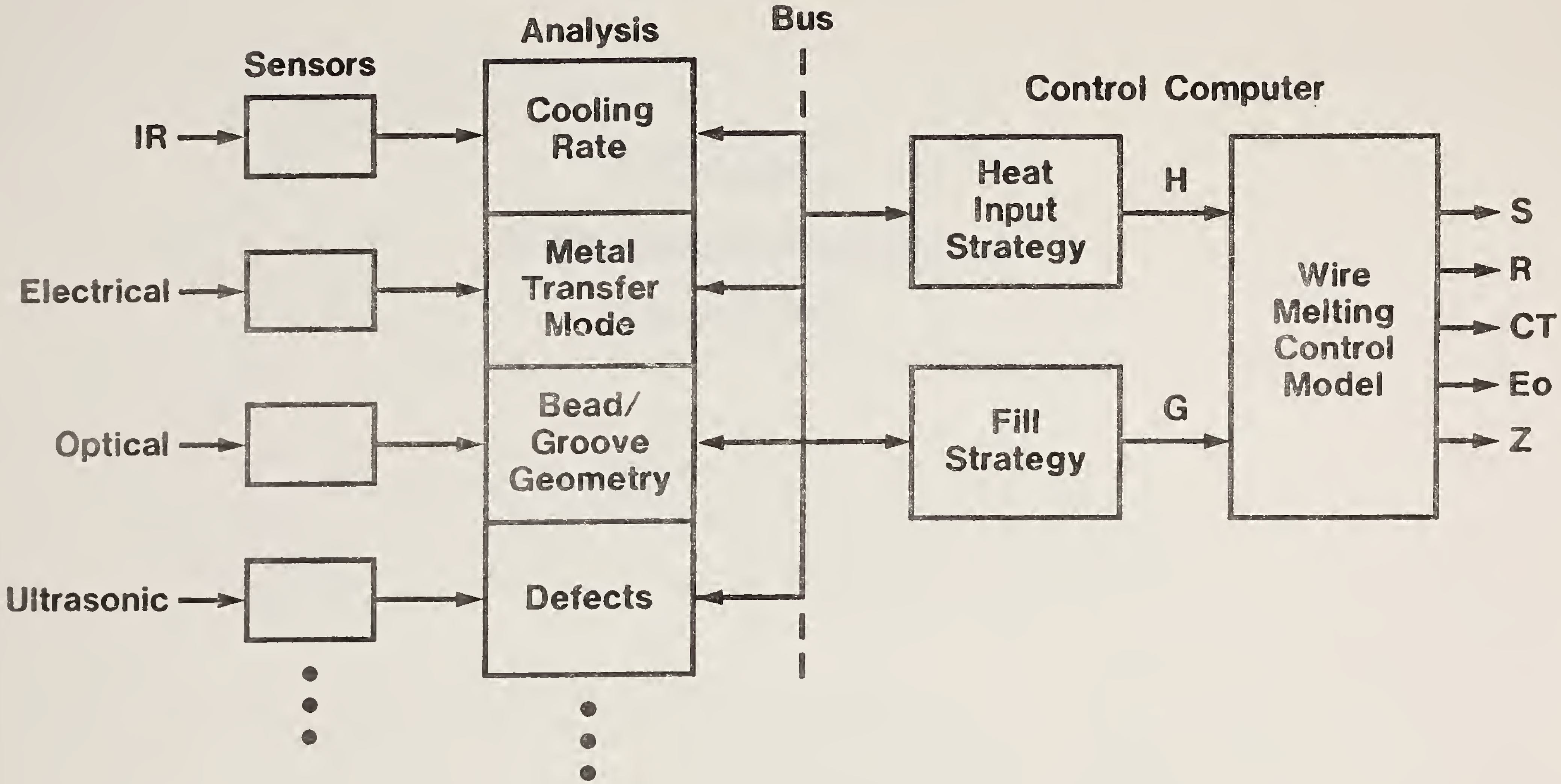
- o Fuel Processing
- o High Level Waste Storage and Treatment
- o Analytical Laboratories

II. Current Status of Remote Handling

- o Stand Alone Robotic/Automated Systems
- o Manually Controlled Mechanical Manipulators
- o Manually Controlled Cranes

III. Needs for Standardization

- Control and Program Languages
- Sensor and Data Input
- Systems Interface and Integration
- Safety and Protective Programs


Sensors
Analysis
Bus
Control Computer
IR
Electrical
Optical
Ultrasonic
Cooling Rate
Metal Transfer Mode
Bead/ Groove Geometry
Defects
Heat Input Strategy
Fill Strategy
H
G
Wire Melting Control Model
S
R
CT
Eo
Z

C7 1548

NIST

SOFTWARE METHODOLOGIES FOR ROBOTIC SYSTEMS IN THE DOE COMPLEX

- Albuquerque Operations Office -

R. W. Harrigan

Sandia National Laboratories

January 30, 1990

NIST

CURRENT COMPUTING & SOFTWARE APPROACHES FOR ROBOT SYSTEMS

- Rocky Flats
  - use commercial robot controller and language environments
  - control using robot controller
  - HP 4000 system control (Fortran 77)
- LANL
  - use commercial robot controller and language environments
  - PC based supervisory (cell) control
  - Pascal and C main programming languages
- SNL
  - use commercial robot controller and language environments
  - SUN, microVax, and Symbolics supervisory control
  - multiprocessor real-time sensor based servo control
  - C and C++ main programming languages
  - developed generalized robot programming environment

NIST

SANDIA'S APPROACH TO SOFTWARE EVOLVED BASED UPON EXPERIENCE WITH ACTUAL SYSTEMS

- Large Number of Diverse Intelligent Robot Systems
  - Robotic Radiation Survey and Analysis System
  - Sandia Pulsed Reactor Maintenance Robot System
  - CAD Directed Robotic Edge Finishing System
  - Nuclear Waste Shipping Cask Head Operations
  - Robotic Silicon Wafer Cassette Handling
  - Robotic Docking of Very Large Down-Hole Waste Transportation Casks
  - High Speed, Swing Damped Transport of Suspended Payloads
  - Robotic Removal of Waste Cask Impact Limiters and Ties Downs
  - Telerobotic Vehicle
  - Robotic Bagout from Gloveboxes
  - Robotic Glovebox Operations at Y-12
  - Robotic Handling of Pu Storage Containers at Pantex
  - CAD based Automated Assembly
  - Robotic Grasping
  - Damping of Oscillations in Flexible Robot Structures
  - and more

- A Need to Do More With Less
  - more efficient software development environments
  - reuseable software

- A Requirement for System Reliability
  - hazardous environments require systems that work
  - live hardware demonstrations

NIST

APPROACH TO DEVELOPMENT OF INTELLIGENT ROBOTIC SYSTEMS

- Integrate Sensing and Intelligence into Commercial Robots
  - faster systems development
  - foster interactions with industry
- Deal with Incomplete Information
  - the systems must work reliably
- Include Operator as an Integral Part of System Control
  - human assisted computer control

NIST

SANDIA APPROACH TO DEVELOPMENT OF INTELLIGENT ROBOT SOFTWARE

- Multiprocessor Computing
  - Suns and Symbolics
  - multiple MC68000 series CPUs in VME backplane
  - special purpose processing
- Structure the Software to Reflect the System Hardware
  - improved communication between hardware and software designers
  - object oriented software environment
- Use Established and Supported Programming Languages
  - C and C++
- Use Established and Supported Operating Systems
  - Unix and VxWorks
- Structure These Environments for Faster Development of Robotic Systems
  - Open System Architecture
    - Intelligent Robot Operating System (IROS)
  - Robot Inpependent Programming Environment (RIPE)
    - Robot Independent Programming Language (RIPL)

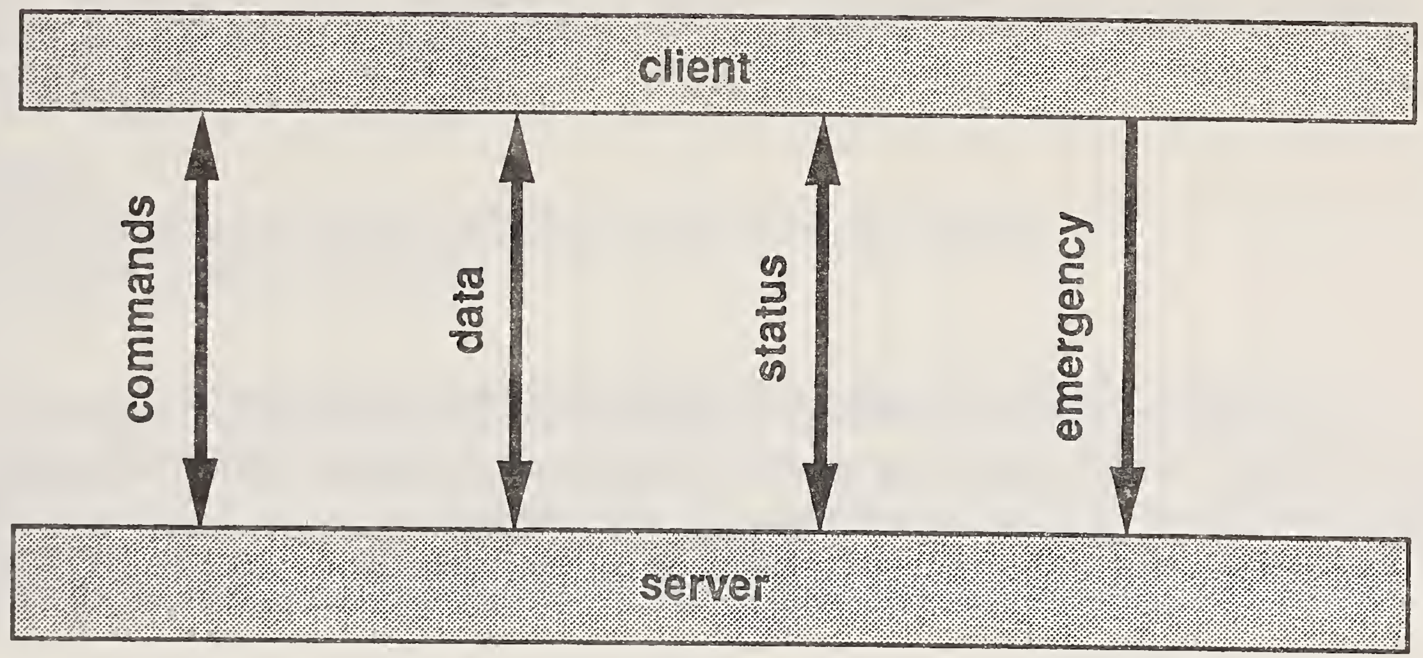
NIST

INTELLIGENT ROBOT OPERATING SYSTEM (IROS)

- Real Time
  - diskless (memory resident)
  - guarenteed minimum interrupt latency
- Multitasking
  - pre-emptive, priority based scheduling
- Multiprocessing
- Software Development Environment
  - familty tree relationships
  - error handler
  - termination handler
- Record Management
  - atomic messages
- Virual Multichannel Communication
  - specific to robot communication requirements

IROS COMMUNICATION

One physical connection (socket)
Four virtual connections



GOAL OF RIPE & RIPL DEVELOPMENT

A Robot Independent Programming Environment and Robot Independent Programming Language should allow the construction of software to control intelligent robot systems by combining existing well-defined software modules rather than writing of code.

- maximize software design and minimize programming

NIST

CHARACTERISTICS OF RIPE & RIPL

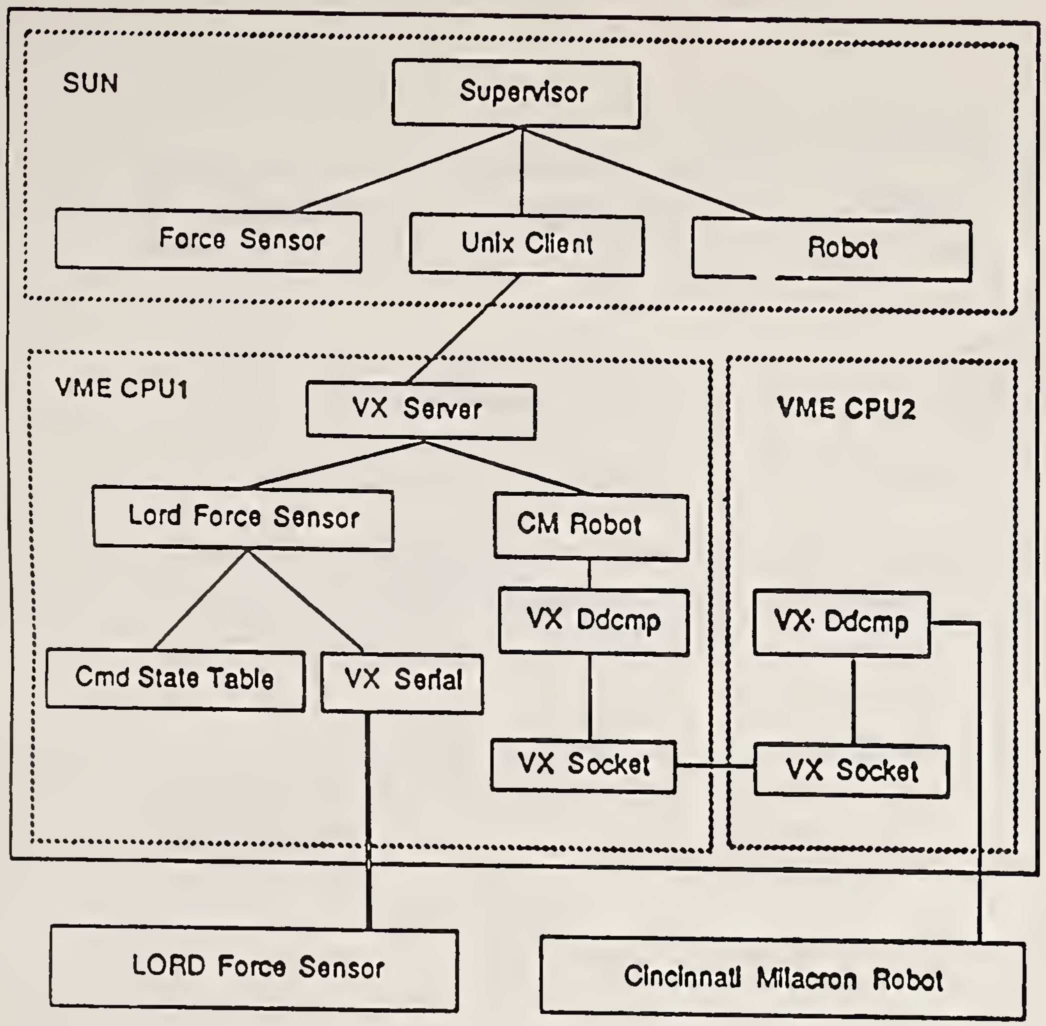
- Reuseability
  - many elements of robot software systems follow common patterns, do not reinvent solutions to old problems
  - catalogs of software modules
- Extensibility
  - rapidly enhance existing systems to perform new tasks
  - incremental problem solving
- Portability
  - new computers, sensors and robots can constantly replace aging systems
  - separate generic from task and device dependent subsystems
- Reliability
  - if the robot system does not perform as desired little else matters

NIST

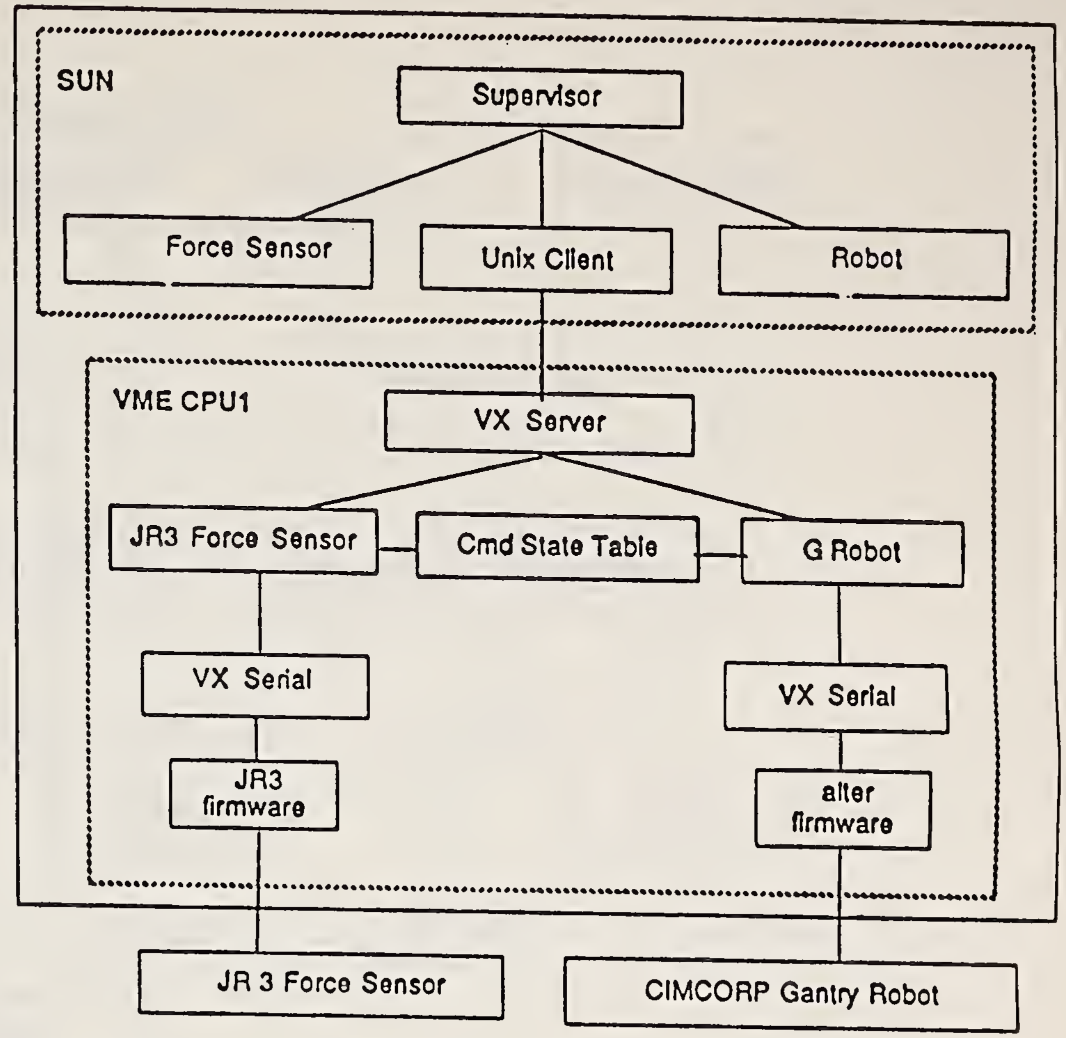
IROS, RIPE & RIPL ARE FUNCTIONING SYSTEMS NOT CONCEPTS

- Operating on Existing Robotic Systems
  - Robotic Radiation Surveys (Cimcorp Gantry Robot)
  - Waste Cask Gas Sampling and Lid Assembly (Cincinnati Milacron T-786 Robot)
- Currently Being Applied to New Robotic Systems
  - Glovebox operations at Y-12 (Schilling Titan Arm)
  - Proximity based docking of waste casks in mines (Cimcorp Gantry Robot)
  - telerobotic mobile vehicle
  - Glovebox bagout operations (GMF Robot)
- UST Robot Control Development
  - 5 months from start to initial demo
  - sensory control
  - graphics for off-line programming and on-line collision avoidance

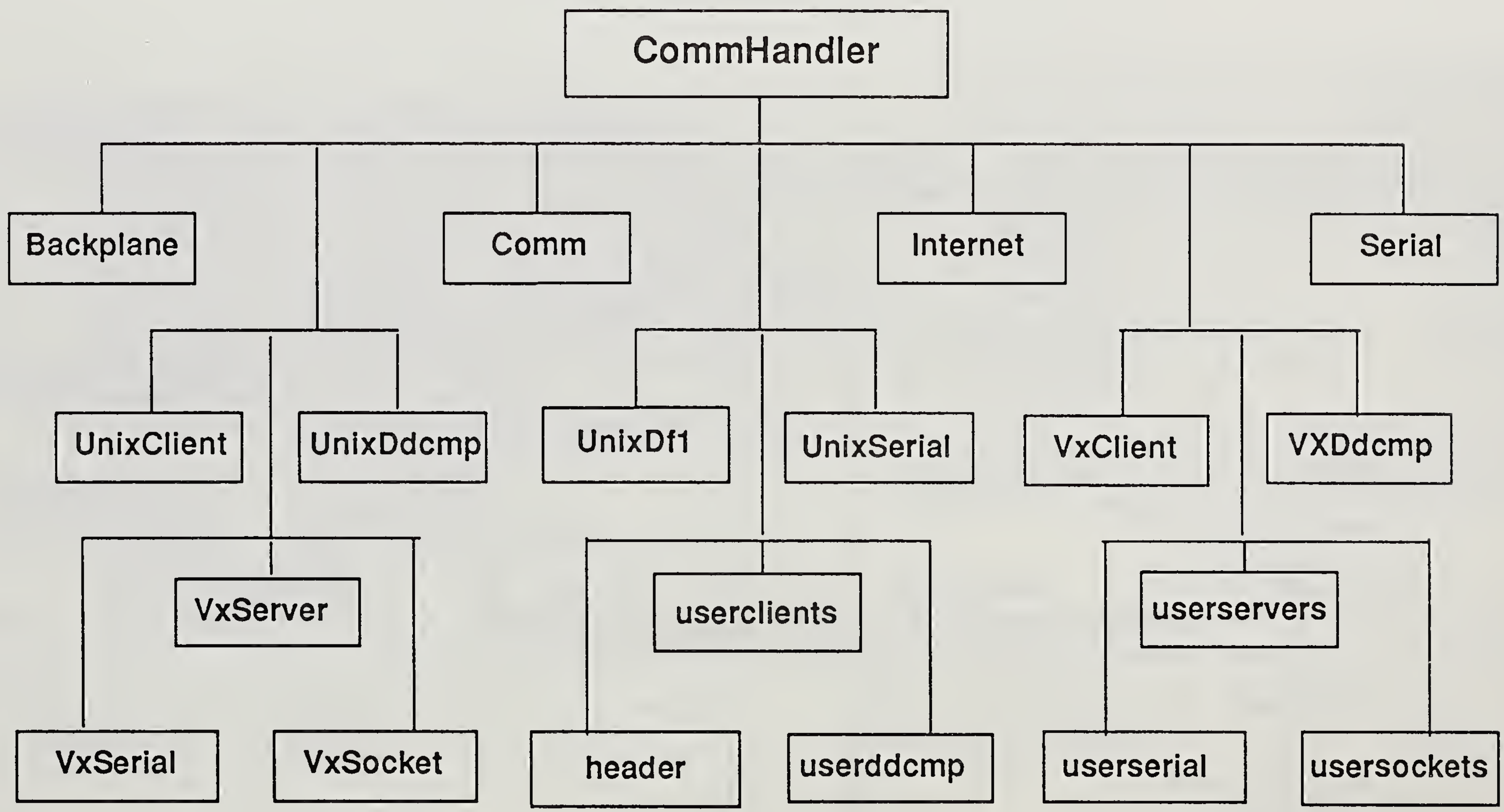
Cask Head Work Cell Example



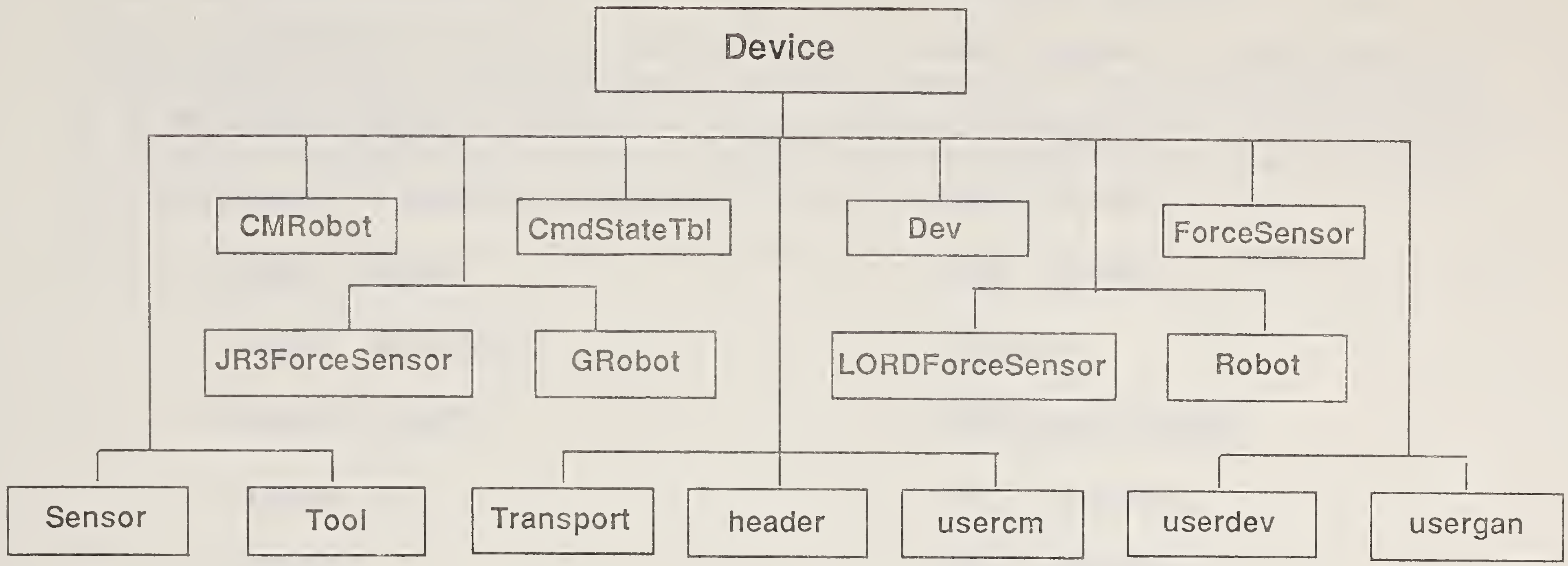
Radiation Survey Work Cell Example



RIPL DIRECTORY STRUCTURE



RIPL DIRECTORY STRUCTURE



RIPL Robot Commands

- move
- move_rel
- move_react
- move_comply
- path_move
- move_home
- approach
- depart
- open_gripper
- close_gripper

- get_effector
- put_effector
- perform (task)
- where
- set_speed
- get_speed
- set_accel
- get_accel
- report_status

The DOE ER & WM RDDT&E Robotics Program should approach the generation of standards for both computing and software by adapting widely used environments to the special needs of robotics for waste cleanup. This will lead to the development of *defacto* standards which derive their generalized use through system developers wanting to use them rather than being forced to use them.

LESSONS LEARNED

NASREM: NASA/NBS Standard Reference Model for Telerobot Control System Architecture

SARTICS: Standard Architecture for Real-Time Intelligent Control Systems

James S. Albus
Chief, Robot Systems Division
Center for Manufacturing Engineering
National Engineering Laboratory
National Institute of Standards and Technology

NASREM MILESTONES

1976	First generation robot Control System (RCS-1)
1980	Automated Manufacturing Research Facility (AMRF) control system design
1982	Robot Control System (RCS-2) integrated into AMRF
1984	AMRF control system operational
1987	NASREM adopted by NASA for Flight Telerobot Servicer (FTS)
1989	FTS contractor selected
1991	FTS development test flight
1993	FTS demonstration test flight
1995	FTS operational for space station first element launch

SPACE STATION
FLIGHT TELEROBOTIC SERVICER

Reduce crew EVA activities

- Assembly tasks
- Maintenance tasks
- Inspection tasks

Location

- Space Shuttle
- Space Station
- Orbital Maneuvering Vehicle

NBS Technical Note 1235

NASA/NBS Standard Reference Model for Telerobot Control System Architecture (NASREM)

James S. Albus, Harry G. McCain, and Ronald Lumia

Robot Systems Division
Center for Manufacturing Engineering
National Bureau of Standards
Gaithersburg, MD 20899

Sponsored by:

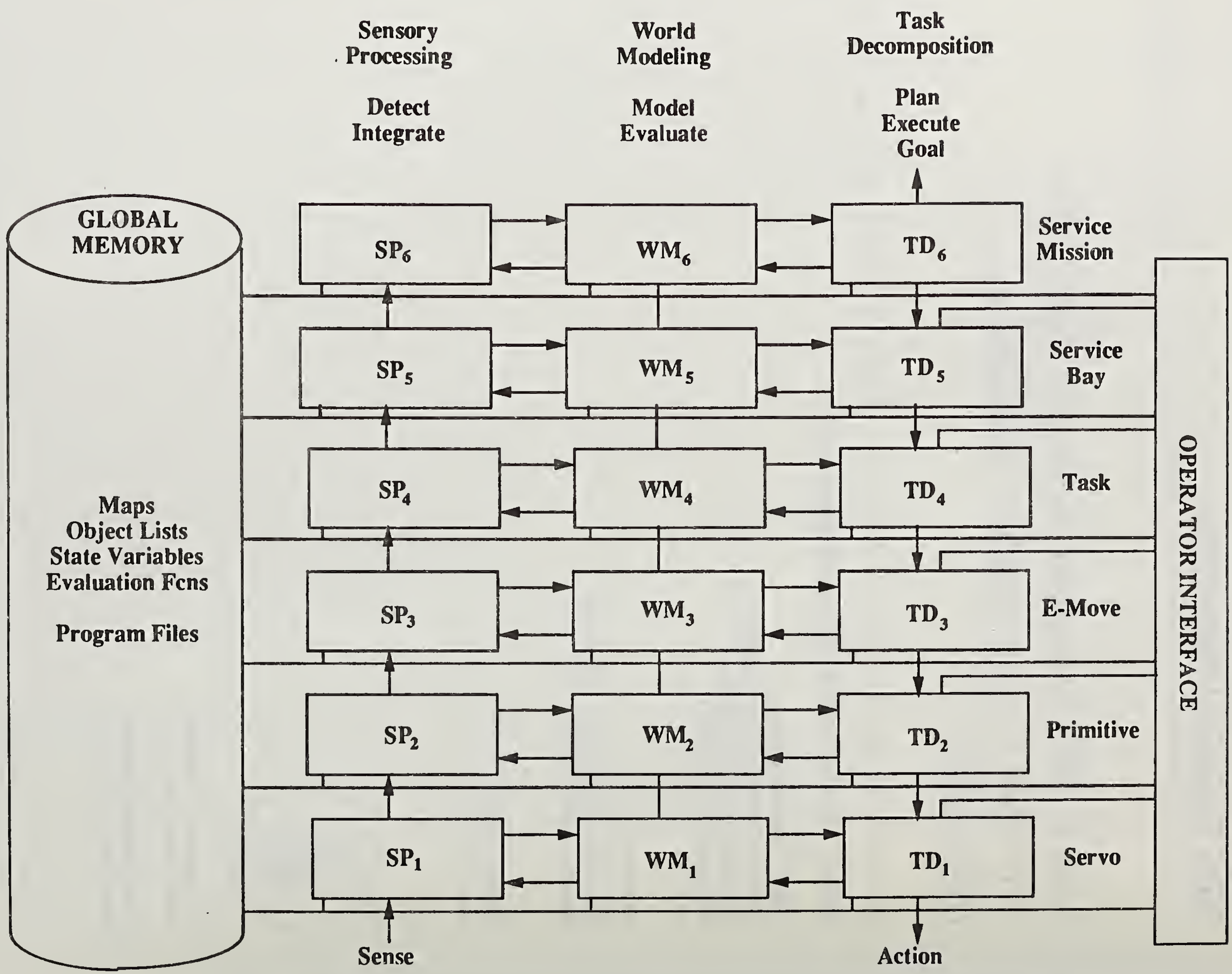
NASA Goddard Space Flight Center
Greenbelt, MD 20771

Revised June 18, 1987
Issued July 1987

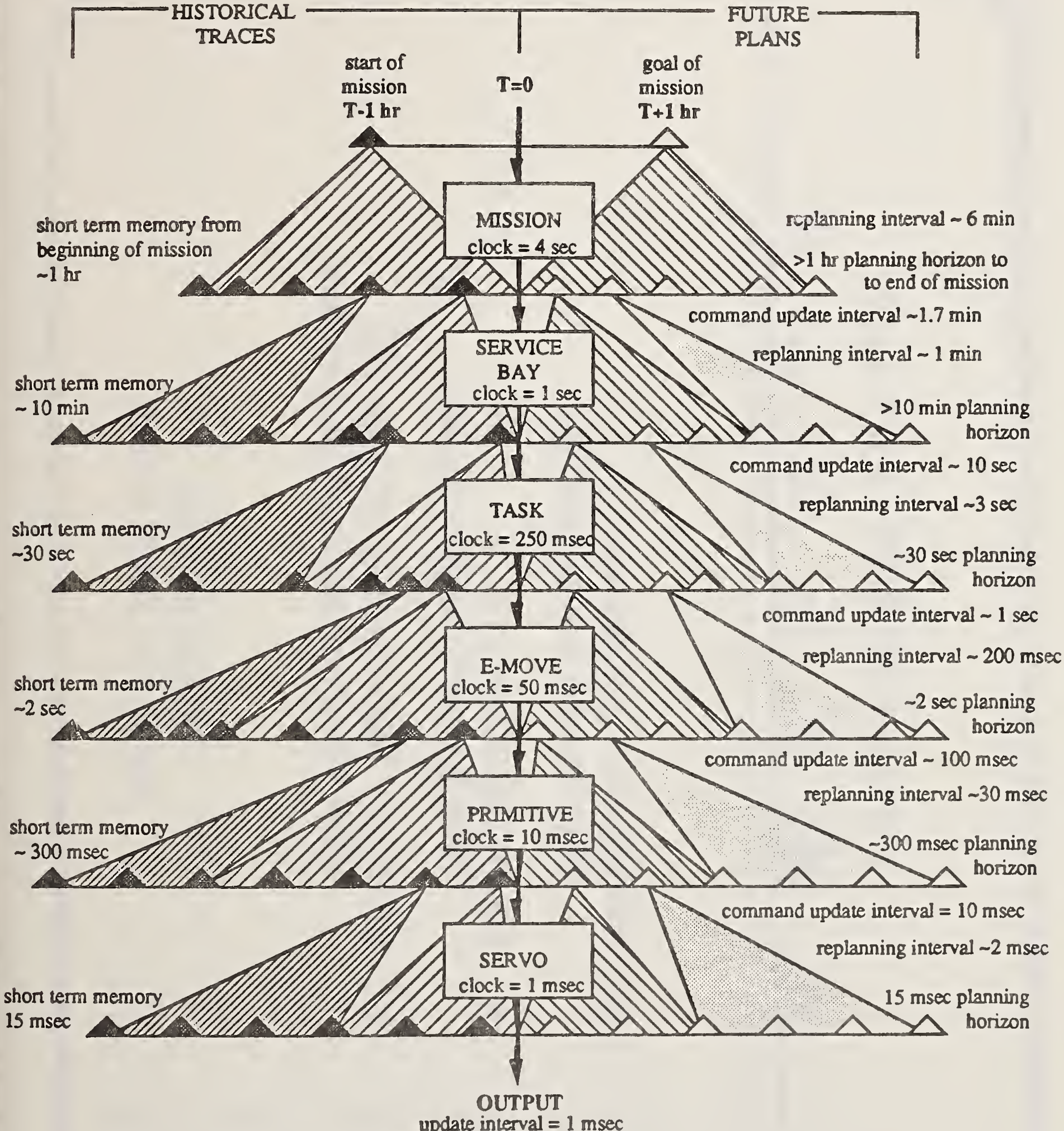
U.S. Department of Commerce
Malcolm Baldrige, Secretary

National Bureau of Standards
Ernest Ambler, Director

NASREM: NASA/NBS STANDARD REFERENCE MODEL

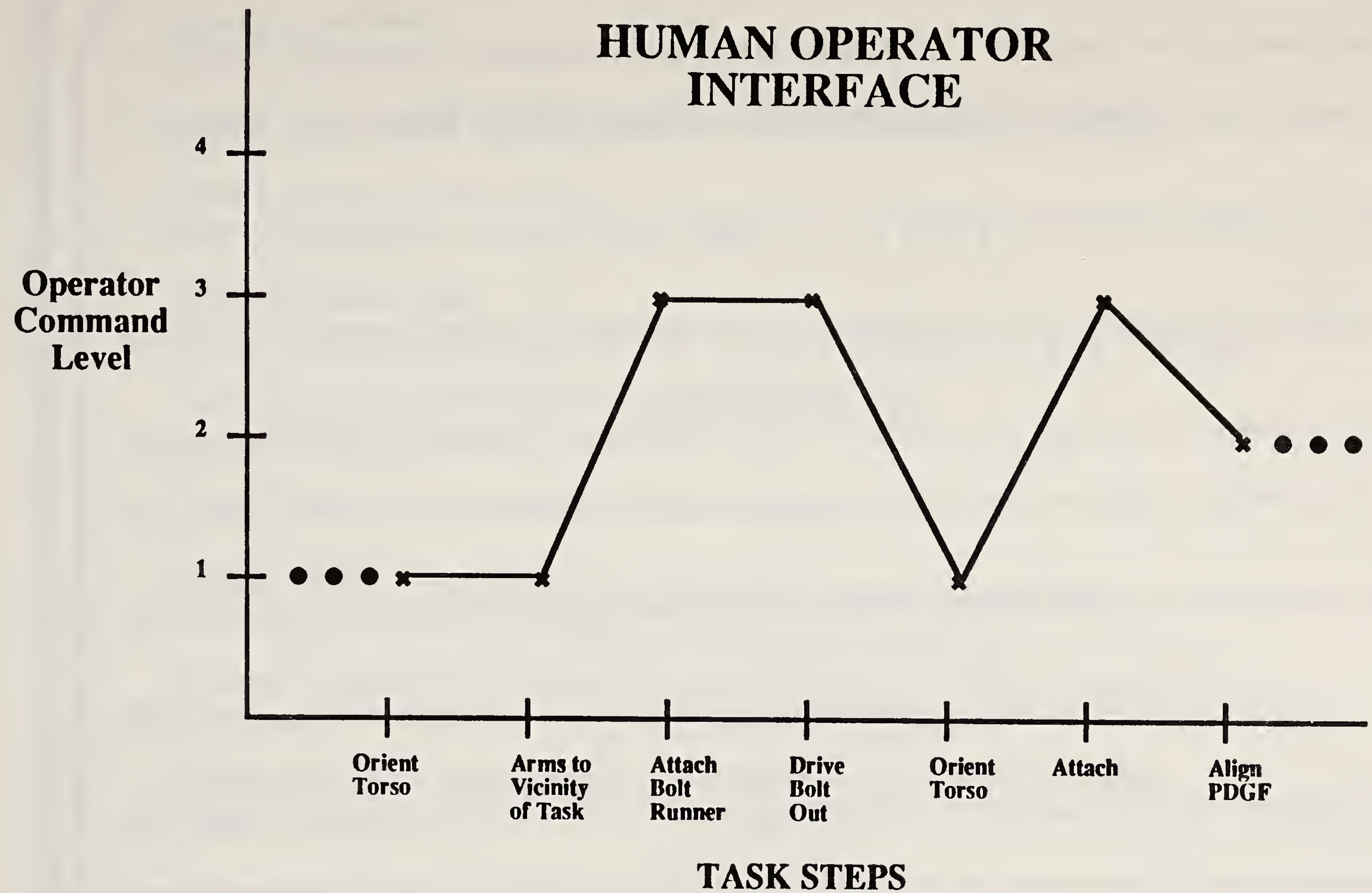


NASREM TIMING DIAGRAM



OPERATOR INTERFACE

- COMMAND INTERFACE
  Allow human to take control
- MODEL INTERFACE
  Allow human to modify models
- SENSORY PROCESING INTERFACE
  Allow humans to interpret sensory data


HUMAN OPERATOR
INTERFACE
Operator
Command
Level
4
3
2
1
Orient
Torso
Arms to
Vicinity
of Task
Attach
Bolt
Runner
Drive
Bolt
Out
Orient
Torso
Attach
Align
PDGF
TASK STEPS

NASREM SUPPORT DOCUMENTS

J.S. Albus, H.G. McCain, R. Lumia, "NASA/NBS Standard Reference Model for Telerobot Control System Architecture (NASREM)," NBS Technical Note 1235, July 1987.

J.C. Fiala, "Manipulator Servo Level Task Decomposition," NIST Technical Note 1255, October, 1988.

A.J. Wavering, "Manipulator Primitive Level Task Decomposition," NIST Technical Note 1256, October, 1988.

J.C. Fiala, "Interfaces to Teleoperation Devices," NIST Technical Note 1254, October 1988.

K. Chaconas and M. Nashman, "Visual Perception Processing in a Hierarchical Control System: Level I," NIST Technical Note 1260, June, 1989.

N. Dagalakis, "Robot Characterization Testing," Intelligent Control Group Internal Report ICG-6, January, 1988.

S. Leake, "A Comparison of ADA and C on Sun and microvax," Intelligent Control Group Internal Report ICG-8, February, 1988.

L. Kelmar, "Manipulator Servo Level World Modeling," NIST Technical Note 1258, March, 1988.

L. Kelmar, "Manipulator Primitive Level World Modeling," Intelligent Control Group Internal Report (in progress).

STANDARD ARCHITECTURE

FOR REAL-TIME

INTELLIGENT CONTROL SYSTEMS
(SARTICS)

FOR

MANUFACTURING AUTOMATION
SPACE TELEROBOTICS
AUTONOMOUS AND SEMI-AUTONOMOUS
MILITARY VEHICLES
AIR
LAND
UNDERSEA
AMPHIBIOUS

EXISTING PROGRAMS

NAVY - NIST -
- Automated Manufacturing Research Facility (AMRF)
- Automated Chemical Analysis Consortium

AIR FORCE - AFWAL - NCMS -
- Next Generation Controller (NGC)

NASA - GSFC -
- Space Station Telerobotics (NASREM)

DARPA - STP -
- Submarine Operational Automation System (SOAS)
- ALV, Pilots Associates, AAV, MAUV

ARMY - LABCOM -
- TMAP, RCC, TEAM, FMR

ARMY - TACOM -
- SAVA

DOE - ORNL - SANDIA
- Environmental Restoration and Waste Management
- Remote Control Vehicles - HERMES

BOM
- Coal Mining Automation

PLUS
- ? Unmanned Aircraft Programs
- ? Robot Submarine Programs
- ? Robot Land Vehicle Programs

COMMON FEATURES

1. Operating System
   Real-time, sensory-interactive multi-processor, multi-tasking

2. Task Decomposition
   Planning, scheduling, path planning, servo control

3. Sensory Processing
   Pattern recognition, spatial/temporal analysis, multi-sensor fusion

4. World Modeling
   Object characteristics, dynamic and kinematic modeling, maps and spatial/temporal representation, state variables

5. Software Development Environment
   CASE tools, debugging, and analysis tools, simulation, gaming

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National Institute of Standards and Technology
10/89

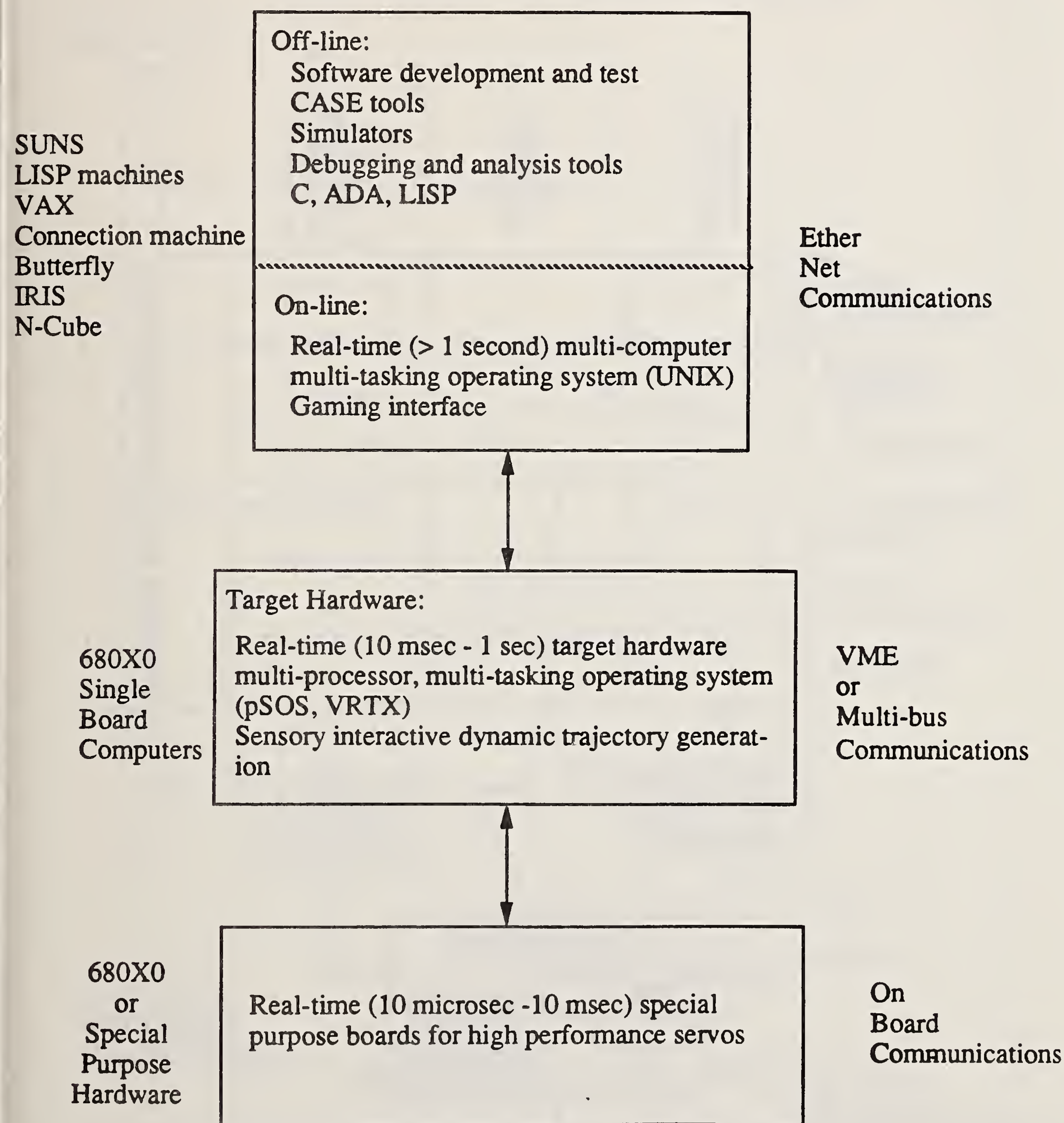
STANDARDS

SARTICS should be an evolving set of standards for:

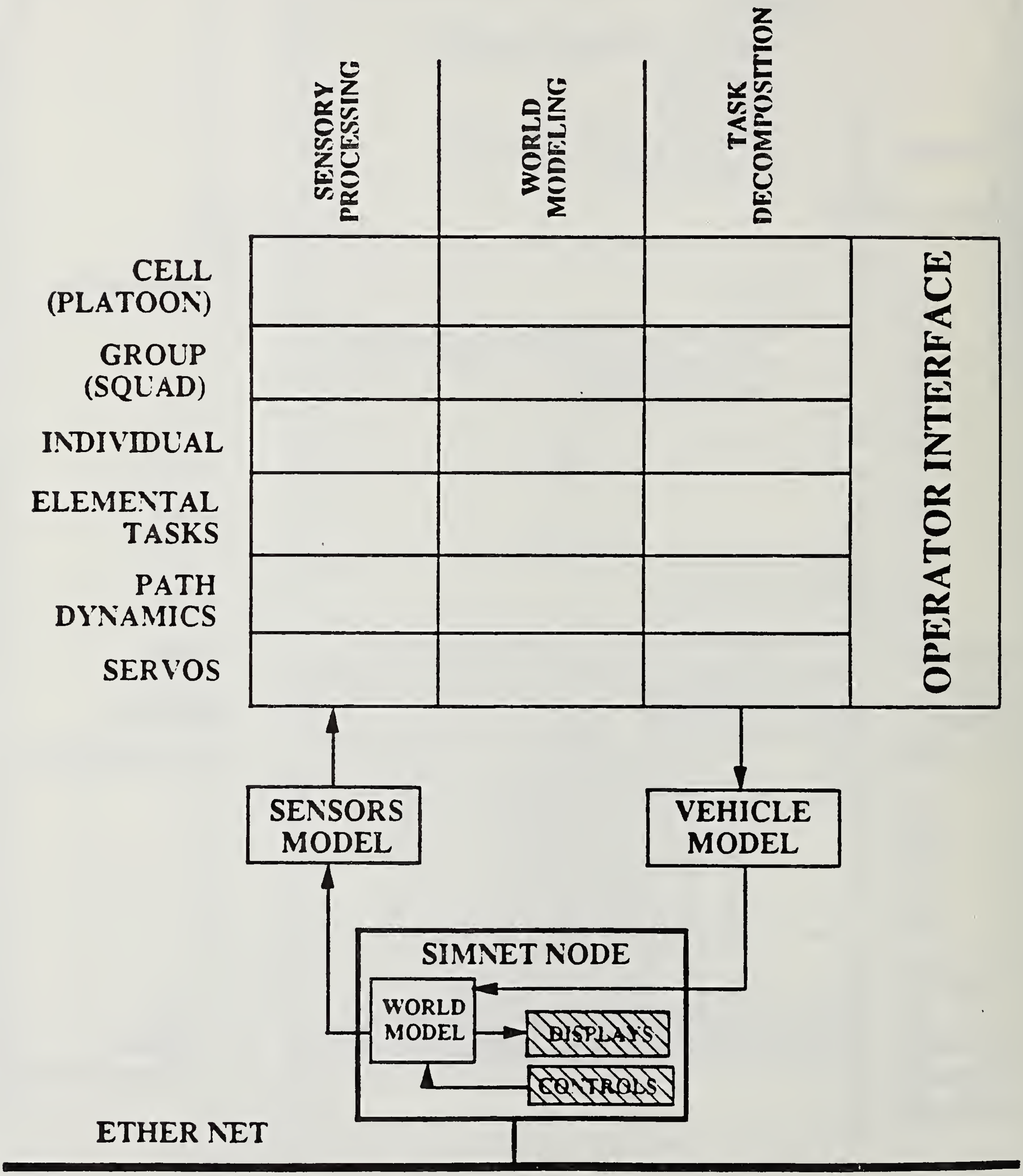
- Task decomposition
- Planning
- World modeling
- Sensory processing
- Computing hardware
- Operating systems
- Software development
- Operator interfaces
- Simulation and animation

SARTICS should be supported by an aggressive research program in system architecture

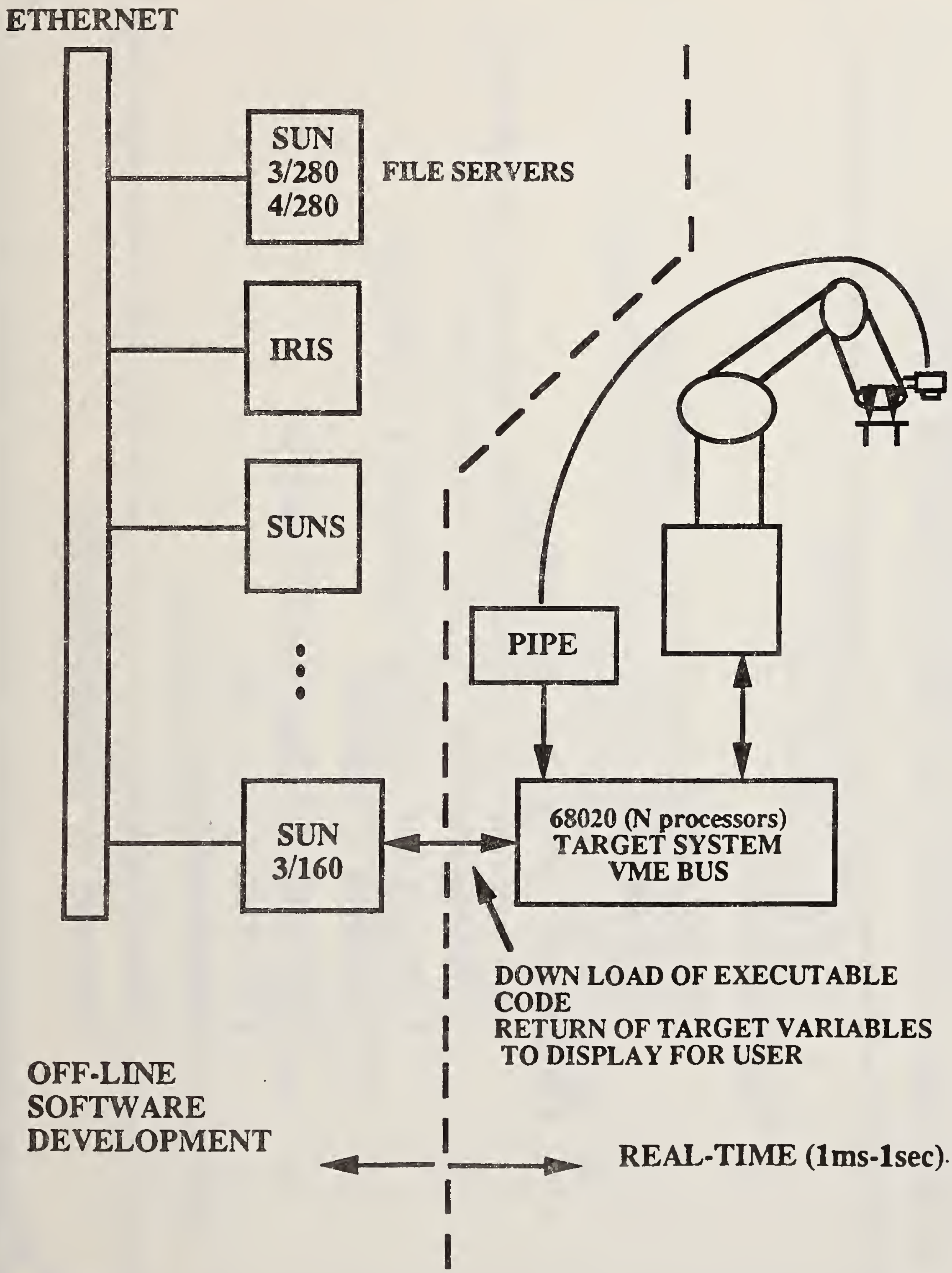
COMMON SYSTEM ARCHITECTURE



STANDARD ARCHITECTURE INTERFACE TO SIMNET



SYSTEM DEVELOPMENT
(View at Hardware)



SARTICS REQUIREMENTS

Extensibility

- **Functional**
- **Temporal**

Human/Computer Interface

- **Teleoperation**
- **Computer-Aided Advisory Control**
- **Traded Control**
- **Human Supervised Control**
- **Human Override**
- **Sensory-Interactive**
- **Autonomous**
- **Shared or Mixed Mode**

BENEFITS

A Standard Architecture will

- Magnify funding resources
- Define interface standards
- Promote modularity of software and hardware
  - Systems can be implemented and upgraded incrementally
- Facilitate technology transfer
  - Military and commercial version compatibility
  - Commercially produced and supported
- Reduce unit cost
  - Increased market size
  - Developmental cost sharing

A standard generic intelligent control system architecture is a key element in international competition strategy

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SARTICS INQUIRY

Respondents

35 Respondents (49% government, 34% industry, 17% academia)

Application areas - Air, land, sea, space, manufacturing, nuclear,mining

9 years average experience in field

Response

Is there a need for SARTICS (32 yes, 1 no, 2 ?)

Wish to be involved in development of SARTICS (25 yes, 1 no, 9 ?)

Most respondents rated the importance of SARTICS midway between "moderately important" and "very important".

SARTICS

* Standard architecture, but unique contents
* User-friendly, graphic interface
* Standard language
* Standard hardware and connectors
* Sharing of common modules or submodules as appropriate (world model or parts, sensor module or parts, etc.)

Use Intersecting Commonalities for Space, Air, Ground, Sea, or Industrial Applications

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10/89

PRODUCT DATA
REPRESENTATION AND EXCHANGE

IGES - PDES - STEP

Status   Development   Implementation

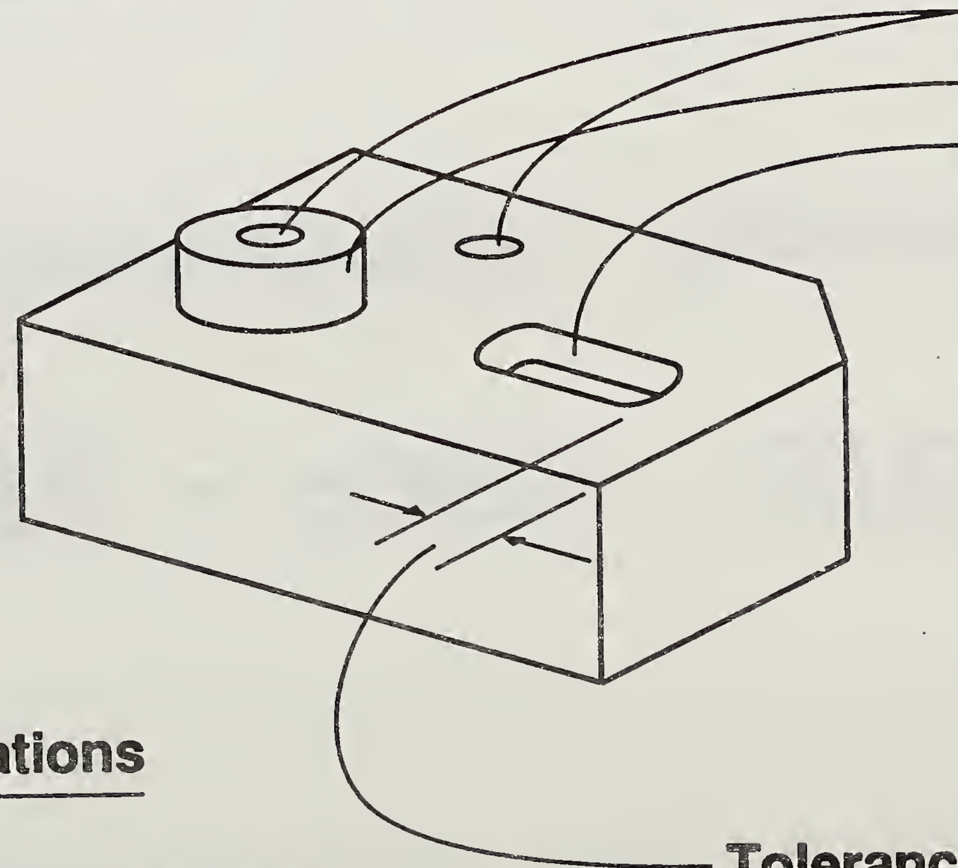
Bradford Smith
National Institute of
Standards & Technology

EXAMPLE PART INFORMATION IN A PDES MODEL

Product ID & Version No.

Feature Definitions

- Holes
- Boss
- Pocket



Surface Finish

- Roughness
- Coating

Shape and Size

- Geometry
- Topology

Material Specifications

- Type
- Composition

Tolerance Specification

- Tolerance type
- Limits on size
- Datum reference

PDES

PRODUCT DATA EXCHANGE SPECIFICATION

AGENDA OF PRESENTATION

- OBJECTIVE
- GOALS OF PDES
- THE PDES AND STEP PROJECTS
- STATUS OF DEVELOPMENT
- FUTURE DIRECTION
- CHALLENGES
- NEEDS

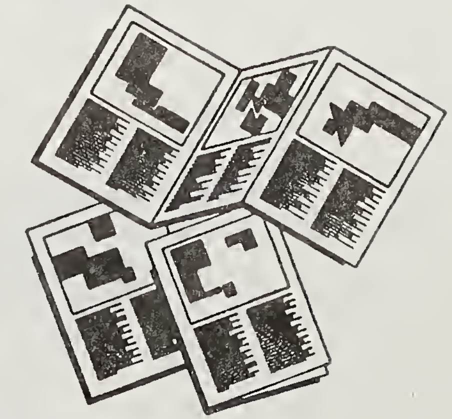
THE PDES OBJECTIVE

- To Develop the Technology for Representation and Exchange of Digital Product Descriptions Supporting Applications Needs Over the Life Cycle of the Product

- To Codify this Technology as a Single International Standard

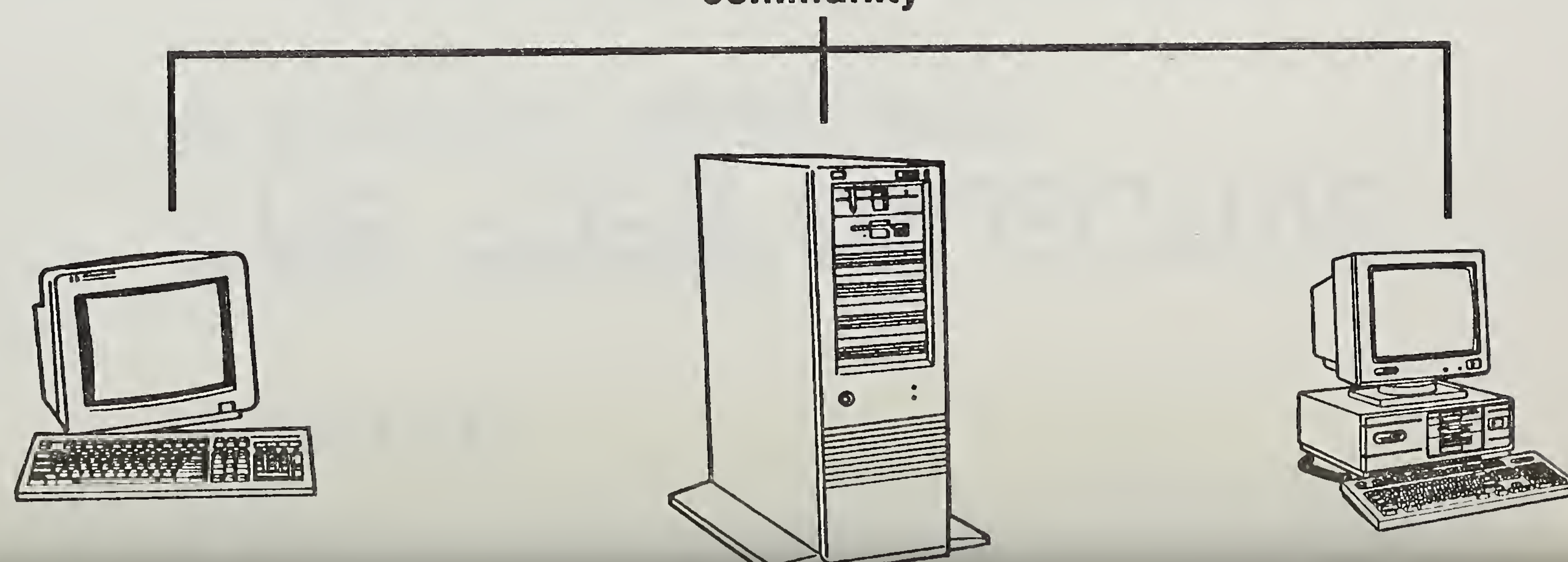
THE PDES OBJECTIVES

To develop the technology
for representation and exchange
of digital product descriptions



To codify this technology as
a single international standard

To ensure quality
implementations across
the vendor/user
community



WHAT IS PDES ???

PDES is:

A Voluntary R & D Effort

A Paper Specification

A Technology Different From IGES

An Exchange Mechanism

A Design for a Product Database

WHAT IS PDES ???

PDES <u>is NOT Now:</u>

An Approved Standard

A Fully Proven Concept

A Replacement for IGES

GOALS FOR PDES

- Exchange Completeness
- Archiving Completeness
- Extensible to Future Versions
- More Efficient than IGES
- Compatible With Other Standards
- Minimum Set of Entities
- Implementation Independence

DOCUMENTS DESCRIBING GOALS

STEP Document 2.0 - Design Objectives

STEP Document 8.0 - Functional Requirements

PDES Initiation Activities Report

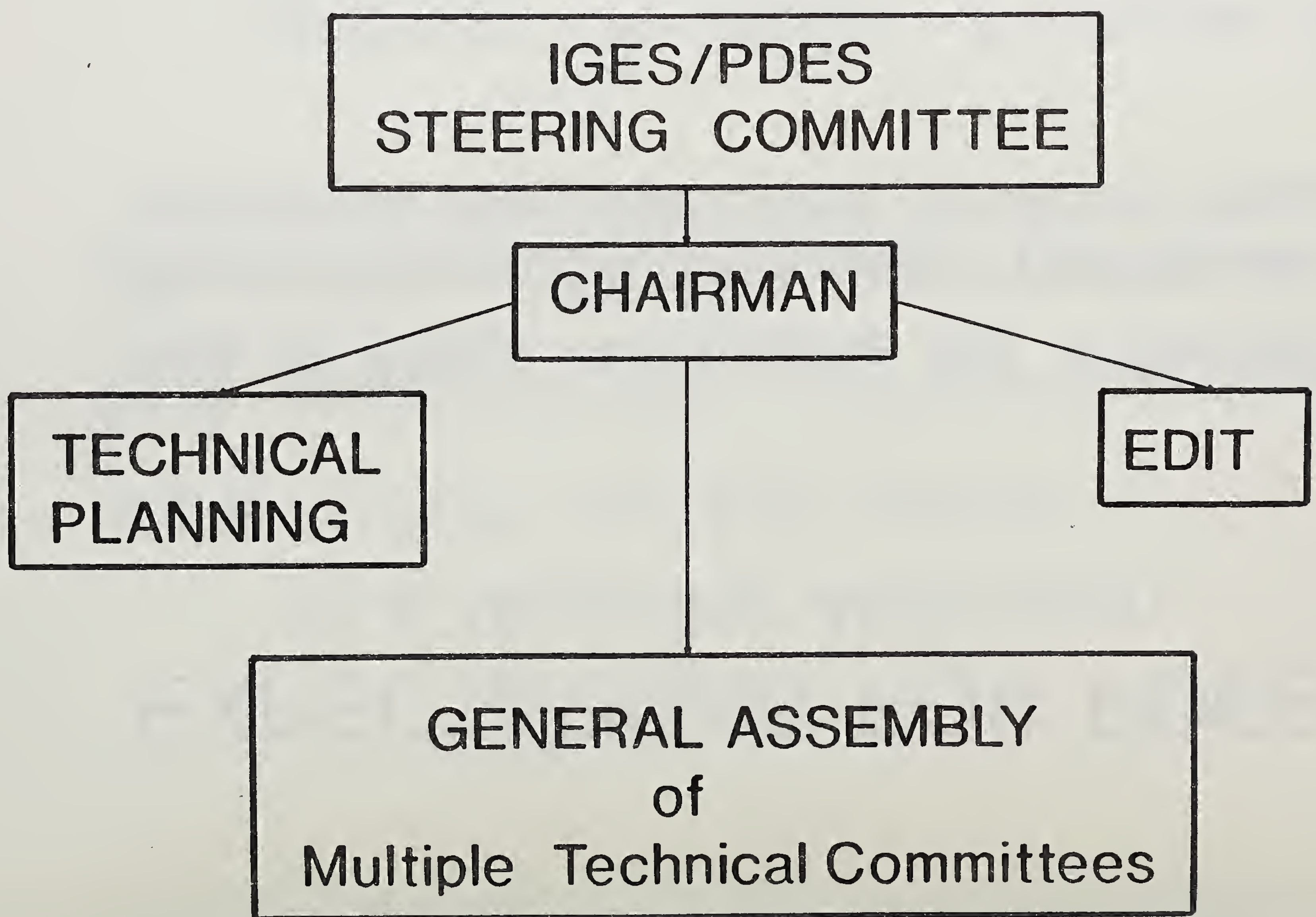
EXPECTATIONS FOR PDES

In a Machining Application

Use of PDES Will Enable the Automatic Generation of Control Data Needed for Advanced Manufacturing Systems Including:

- Automatic Generation of Process Plans
- Creation of NC Cutter Path Data
- CMM Control Data Generation

THE IGES/PDES ORGANIZATION



IGES/PDES ORGANIZATION

Current PDES Related Projects

- PDES/STEP Version 1.0 Balloting
- Implementation Guidelines
- Experimental Testing
- Test Case Development
- Related Documentation Development

BULLETIN BOARD SYSTEM

IGES ELECTRONIC BULLETIN BOARD

(301) 963 - 6234

1200 Baud 8 Bits 1 Stop

Agendas	Draft Documents
Minutes	Software
Bylaws	Test Cases
PDES Models	Test Procedures

PROJECT MANAGERS

- IGES — Dennette Harrod Jr
- PDES — Tony Day
- Testing — Mark Pearson
- ISO — Jerry Weiss

STEP

STANDARD FOR THE EXCHANGE OF PRODUCT MODEL DATA

SC4 MEMBERSHIP

- 16 Participating Countries
- 8 Observing Countries
- 6 Liaison Organizations

- 145 Participating Experts

STEP DOCUMENTATION

- Management and Technical Overviews
- Functional Requirements
- Project Plan and Work Status
- Information Models
- Guidelines for Implementation
- Guidelines for Use
- Glossary and Open Issues

PDES AND STEP

A Comparison

SAME OBJECTIVES

SAME SCHEDULE

OVERLAPPING PERSONNEL

JOINT MEETINGS

PDES and STEP

Minor Differences

Different Committees

Different Rules

In STEP, US Has One Vote

DEFINITIONS

It Is Important To Keep Projects in Perspective

PDES 1.0	Testing Drafts
	Working Draft of V1.0
	Work Stopped on V1.0
STEP 1.0	PDES Formed WD of V1.0
	WD Registered as Draft Proposal
	First DP Sent for Ballot
	Top Priority Project

CONTENTS OF VERSION 1.0

- Geometry
- Features
- Tolerances
- Mechanical Parts
- Drafting
- Finite Element Analysis
- Electrical Assemblies

NORMATIVE ANNEXES

STEP Draft Proposal

A. MODELING LANGUAGE - EXPRESS

B. PHYSICAL FILE STRUCTURE

C. MAPPING to the PHYSICAL FILE

INFORMATIVE ANNEXES

STEP Draft Proposal

D. INFORMATION MODELS
   Formerly Called Volume 3

E. DEVELOPMENT SUPPORT
   Implementation Guide
   Test Parts
   Software Tools

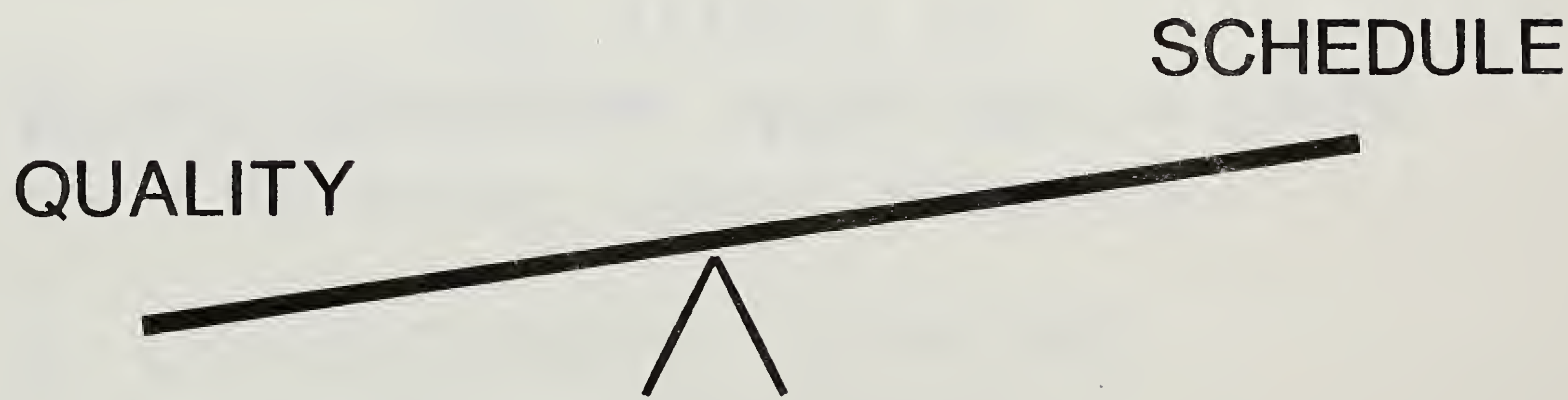
FUTURE DIRECTION

How to Determine When We're Done
with Version 1.0

Completeness

Integration

LIMITED RESOURCES
In the IGES/PDES Organization



What is the Best Balance ?

THE CHALLENGES AHEAD

- HOW TO DISTRIBUTE THE DOCUMENT
- HOW TO REVIEW THE CONTENT
- HOW TO VALIDATE THE MODELS
- HOW TO CONTROL CONFIGURATION
- HOW TO ENSURE COORDINATION
- HOW TO ENCOURAGE IMPLEMENTATIONS

- CHALLENGE -

HOW TO DISTRIBUTE THE DOCUMENT

- PAPER FORM BY MAIL
    - 2100 Pages
- ELECTRONIC FORM
    - Present Form
        - ASCII Characters
        - LaTeX Encoding
        - Paper Form Figures
    - Need for New Form ?
        - Hypertext
    - Formats for Transmission

- CHALLENGE -

HOW TO REVIEW THE CONTENT

- SCOPE IS VERY BROAD
- SEEN AS MOVING TARGET
- MANY COMMENTS EXPECTED
- PHILOSOPHICAL DIFFERENCES

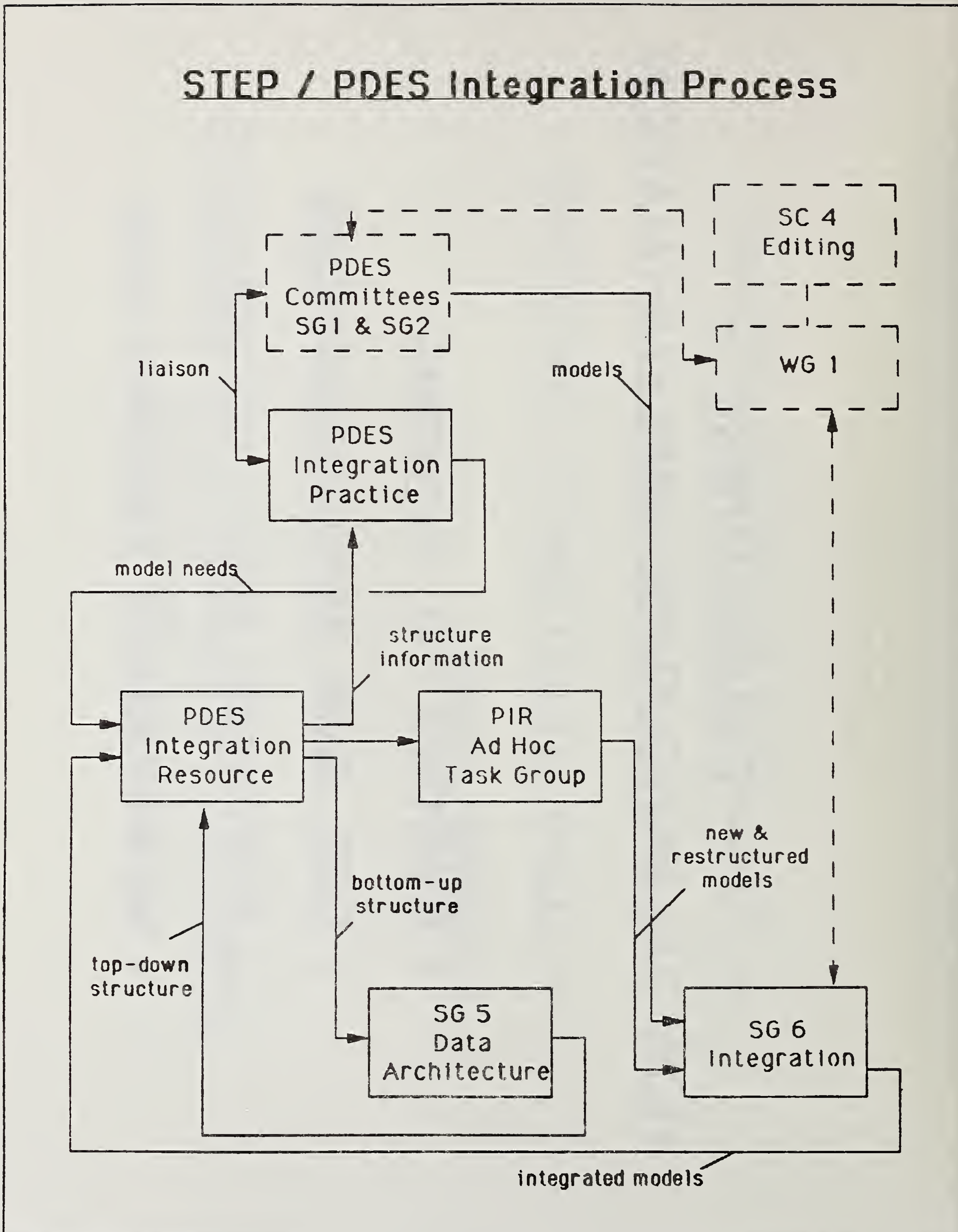
- CHALLENGE -

HOW TO VALIDATE THE MODELS

- ISSUE LOGS
- STRUCTURED WALK-THROUGHS
- APPLICATION QUERIES
- SOFTWARE IMPLEMENTATIONS

- CHALLENGE -
HOW TO ENCOURAGE IMPLEMENTATION

- EXISTING CAD SYSTEMS
- DATA BASE IMPLEMENTATIONS
- SOFTWARE TOOLS NEEDED
- MIGRATION OF EXISTING DATA


STEP / PDES Integration Process
SC 4
Editing
PDES
Committees
SG1 & SG2
WG 1
liaison
models
PDES
Integration
Practice
model needs
structure
information
PDES
Integration
Resource
PIR
Ad Hoc
Task Group
new &
restructured
models
bottom-up
structure
top-down
structure
SG 5
Data
Architecture
SG 6
Integration
integrated models

PDES NEEDS

- Committment for Technical Review
- Completion of Model Integration
- Development of Application Protocols
- Active Management of Work Elements
- Mechanisms for Identifying Needs
- Techniques for Setting Priorities
- Better Supporting Documentation

FORCING FUNCTIONS FOR PDES

- DOD Military Standard 1840A
- PDES Inc. Cooperative
- DOD CALS Program
- International Committment
- Major R&D Funding Worldwide

NEXT GENERATION COMPUTER RESOURCES PROGRAM OVERVIEW

The Navy's Next Generation Computer Resources (NGCR) program will provide the framework for standardized embedded computer hardware and software products for all Naval weapons systems in the mid-1990's and beyond through a set of commercially-based interface and protocol standards. It will assure that mission critical computer hardware and software, produced to perform the same types of functions as current AN/UYK-20, AN/UYK-43, AN/UKY-44, AN/AYK-14, AN/UYS-1 and AN/UYS-2 computer systems, will be interoperable within and between systems regardless of manufacturer or technology used (technology independence). NGCR standards will be applied to all mission critical computer resources employed ashore and on shipboard and airborne platforms, and will encompass low, medium and high levels of performance to meet the diverse computer processing needs of future Naval systems.

The NGCR program will implement an Open Systems Architecture (OSA) concept. This OSA approach focuses only on the standardization of widely accepted non-proprietary hardware and software interfaces, protocols and form and fit factors. An OSA based on commercial standards permits multiple vendors to develop products which meet a given published standard. A simplistic analogy is the IBM PC-compatible market which has sprung up around the published IBM standards for its PC family. This high level of standardization provides for a number of important benefits including: regular and rapid infusion of new technology, increased number of potential suppliers, availability of modular/adaptable designs, and lower costs due to competition. Industry has indicated a strong consensus in favor of an OSA approach. An OSA based on commercial standards will allow industry to use, to the maximum extent possible, commercially-based design tools and products to meet Navy system needs.

The central feature of the NGCR program and that which makes it unique as a Navy acquisition program is the definition of **joint** industry and Navy standards. The emphasis on "jointly" defined standards serves two purposes: first, to draw heavily on current trends and practices in use in the commercial market-place and thereby lessen Navy development funding expenses, and second to broaden the potential base of suppliers leading to increased competition for procurement of systems, systems upgrades and spare parts. This standards-based approach is fully consistent with and supportive of the open system architecture concept described previously.

There are two primary NGCR program objectives: 1) provide increased operational readiness and effectiveness, and 2) provide increased flexibility for program managers developing systems with computer resources. The NGCR program has been structured to attain the first objective by facilitating rapid and effective fielding of functional changes in response to changing threats, by increased operational availability and by reduced life cycle costs. The mechanisms by which these will occur are: the application of the latest computer resources architecture and component technologies, system modularity, fault tolerance, increased competition, system commonality and interoperability, as well as the applicability of commercially available standards and designs. The second objective will be accomplished by assuring a variety of Navy approved products is available for weapon system designers across the range of performance levels. The NGCR program will provide system designers with the flexibility to apply totally integrated computer systems with assurance of intra- and inter-platform operability.

To achieve these objectives, the NGCR program will establish a set of computer hardware and software interface and protocol standards in ten (10) areas, using a phased approach.

STANDARDIZATION AREAS

MULTIPROCESSOR INTERCONNECTS
- BACKPLANE (1992)*
- HIGH SPEED DATA TRANSFER NETWORK (1994)
- HIGH PERFORMANCE BACKPLANE (1997)

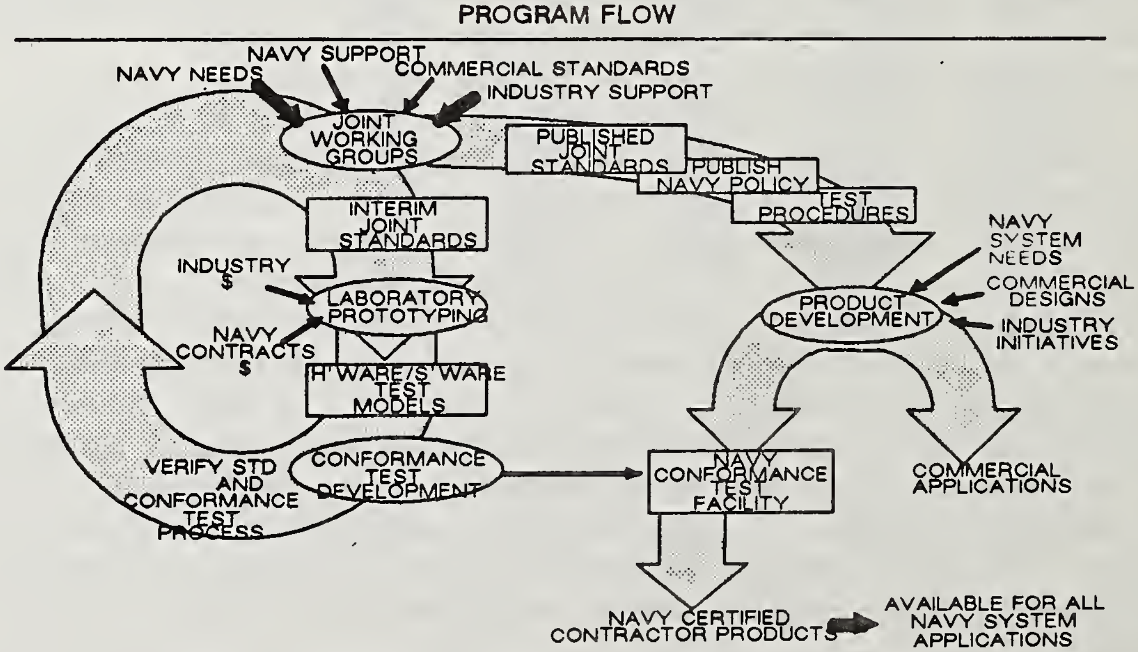
MULTISYSTEM INTERCONNECTS
- SAFENET I / LOCAL AREA NETWORK (1990)*
- SAFENET II / LOCAL AREA NETWORK (1991)*
- HIGH PERFORMANCE LOCAL AREA NETWORK (1998)

SOFTWARE STANDARDIZATION AREAS
- OPERATING SYSTEM (1996*; 1998 MLS)
- DATA BASE MANAGEMENT SYSTEM (1998)
- PROGRAMMING SUPPORT ENVIRONMENT (1998)
- GRAPHICS LANGUAGE / INTERFACE (1998)

* CERTIFICATION OF PRODUCTS THROUGH NGCR

These standards will be defined jointly by the Navy and industry, and will take maximum advantage of ongoing commercial trends and standardization activities. Laboratory test models will be procured to assist in the validation of the standards, development of conformance test procedures and verification of interoperability among all NGCR standards. NGCR will develop a conformance testing program to test all NGCR products for compliance with the NGCR standards prior to full product manufacturing and deployment. The program is currently structured to acquire laboratory models and develop certification capabilities for four (4) of ten (10) NGCR standards. The remaining six (6) standards will rely completely on industry initiatives to solidify the standards and perform conformance testing. Successfully tested NGCR products will be certified as conforming to NGCR standards and placed on a certified products list for application to future weapons systems development.

PROGRAM FLOW



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10. SUPPLEMENTARY NOTES

[ ] DOCUMENT DESCRIBES A COMPUTER PROGRAM; SF-185, FIPS SOFTWARE SUMMARY, IS ATTACHED.

11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

At the request of the Department of Energy's (DOE's) Office of Technology Development the National Institute of Standards and Technology (NIST), Robot Systems Division organized and hosted this first DOE/NIST Workshop on Common Architectures for Robotic Systems. The Workshop was held at the Marriott Hotel in Gaithersburg, Maryland, on January 30-31, 1990.

This workshop had three goals:

(1) An initial review of the methodologies currently used by the DOE sites for development and maintenance of software related to robotic and remote systems.

(2) Presentations by representatives of other government agencies on lessons learned in the development of common architectures for robotic and remote systems.

(3) A preliminary assessment of the methodology necessary to arrive at a DOE common architecture.

DOE sponsored this workshop as a first step toward considering the potential roles and benefits that common robotic architectures could play in fulfilling DOE's Environmental Restoration and Waste Management (ER&WM) robotic technology program objectives. NIST hosted the workshop as a means of promoting robot technology advancement and technology transfer through the development of voluntary standards and guidelines.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)

control system architectures; intelligent machines; real-time control systems; robot control systems; robotic standards; robotics; teleoperation

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