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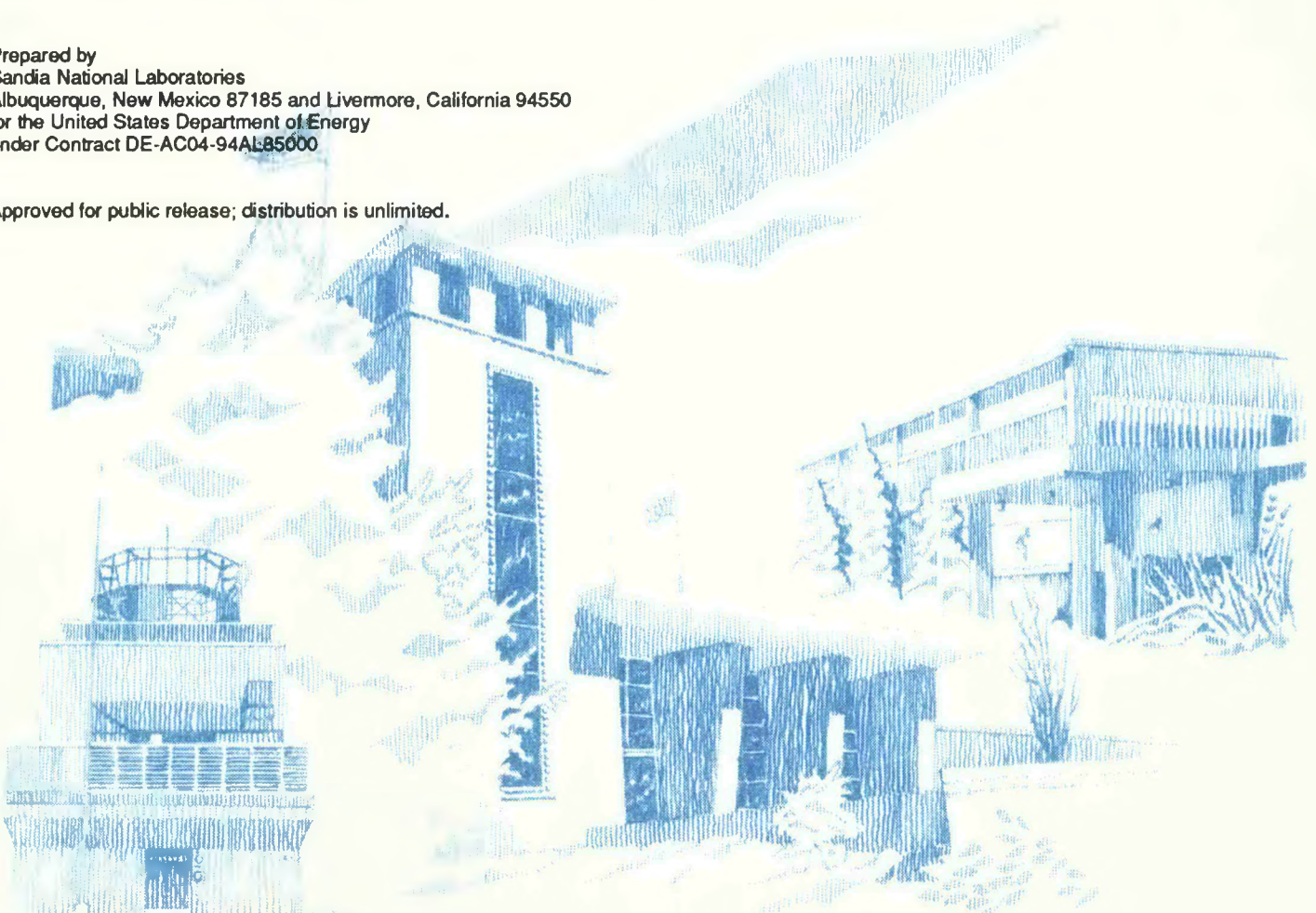
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View Graph Presentations of the Sixth DOE Industry/University/Lab Forum on Robotics for Environmental Restoration and Waste Management

Hosted by the Intelligent Systems and Robotics Center

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550
for the United States Department of Energy
under Contract DE-AC04-94AL85000

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**View Graph Presentations
of the
Sixth DOE Industry/University/Lab Forum
on Robotics for
Environmental Restoration and Waste Management**

sponsored by the
Department of Energy

hosted by
Sandia National Laboratories

at the Albuquerque Convention Center
August 16 - 17, 1995

Abstract

This document records view graphs of talks presented by principal individuals responsible for activities indicated by the title. It also contains location information of the other presenters and registrants of the conference.

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This work was performed at Sandia National Laboratories supported by the US Department of Energy under contract number DE-AC04-76DP00789.

AGENDA

Sixth DOE Industry/University/Lab Forum on Robotics for Environmental Management

August 15, 1995

6 - 9 pm Registration

Convention Center Upstairs East

August 16, 1995

General

7:45 am Registration

Convention Center Upstairs East

8:15 am Welcome and introduction of speakers

8:30 am Keynote speech

U.S. Representative Steven H. Schiff

**9:00 am OTD Robotics Technology Development Program
Overview**

Lin Yarbrough, PhD, DOE/HQ

Ongoing RTDP Activities

9:15 am Contaminant Analysis Automation

Robert Hollen, Los Alamos National Lab

10:00 am coffee

10:15 am Decontamination & Decommissioning

Bill Hamel, Oak Ridge National Lab.

11:00 am Mixed Waste Operations

**Bruce Wilding, Idaho National
Engineering Laboratory**

11:45 am lunch break

1:45 pm Landfills

**Clyde Ward, Westinghouse Savannah
River Company**

2:00 pm Tank Waste Retrieval

Barry Burks, Oak Ridge National Lab.

2:30 pm Cross Cutting & Advanced Technology Development

Dan Horschel, Sandia National Labs

3:15 pm coffee and discussion

Requirements Workshop Sessions
Morning of August 17, 1995

The second half day of the forum will consist of a series of workshop sessions which focus on the definition and discussion of ER&WM robotics in the basic areas included in the Robotics Technology Development Program. The objective of these sessions will be to provide greater detail about the technology needs and approaches. *The perspective will be from a technology point of view.* This approach will give an unconstrained atmosphere to consider opportunities for potential robotic solutions to the challenging problems we face.

Times	Track 1	Track 2	Track 3	Track 4
8-9:45	World Model Mapping Systems - Allowing Robotics to Work in Unstructured Environments	Contaminant Analysis Automation - Coming of Age	Data Characterization - Obtaining the Data and Understanding It	The University Connection to DOE EM
	Charles Little, SNL Mongi Abidi, U. Tenn.	Bob Hollen, LANL Bruce Wilding, INEL	Clyde Ward, SRTC Randy Roberts, LANL	Jerry Stauffer, SNL Dan Horschel, SNL
	UT Mongi Abidi UF Jim Tulenko CMU Martial Hibert SPAR Julian Millard JPL Larry Matthies	Booths and demonstrations	Understanding Radiation Floor Surveys - Clyde Ward SRTC Qualitative Assessment of Gas Chromatograms - Sharbari Lahri LANL Data Fusion - John Feddema SNL Finding Rust, Streaks, Dents and Blisters on Drums - Lorretta Huber LLNL Finding Buried Containers with Multiple Sensors - Ed Hensel NMSU	8:00 GA Tech 8:15 Purdue 8:30 CWRU 8:45 Rice 9:00 Penn. State 9:15 CO. Mines 9:30 Wash. Univ.
9:45-10:15	break	break	break	break
10:15-12:00	Industry and the RTDP - Working Together to Solve EM Problems	Integrated Work Systems - More Than Just a Robot	Technical Task Area Discussions	10:15 U. Minn. 10:30 CMU 10:45 CMU 11:00 U. Fla. 11:15 U. Tenn. 11:30 U. Wisc
	Mark Evans, PNL Bruce Wilding, INEL	Bill Hamel, ORNL Don Herman, FERMCO	Lin Yarbrough, DOE Dave Geiser, DOE	

Lunch break

CC&AT Technology Demonstrations

1:00-5:00 pm, Sandia National Laboratories
(Bus leaves the hotel at 1:00 pm, leaves Sandia at 4:30 pm)

In response to many requests from attendees at last year's CC&AT tours, this year we will again be hosting an open house, with demonstrations, poster sessions and videos running continuously from 1:30 to 4:30 pm. A CC&AT demonstration tour map will be available which will guide you to the demonstration sites at Sandia. If your schedule requires it, you may drive a personal/rental car to the demonstrations (but you must stop at the entrance gate to Kirtland AFB for a one-day base sticker, which will require that you comply with Kirtland AFB entrance regulations - current license, insurance, and anti-pollution certification). If you do not choose to drive, busses will be available for at least 100 riders. Please note that citizens of foreign countries may be required to be escorted while viewing the demonstrations.

SNL demos:

- 1) SANCHO task-based interface to perform tasks with gantry robot (e.g., "put that over there").
- 2) Coordinated multi arm control using SMART with dissimilar robots.
- 3) Dataglove input for operator control of robot motions and tasks, including previewing actions in simulations.
- 4) System Composer for rapid integration of software (including simulations) with hardware.
- 5) SMART module showing near-real-time system dynamics in simulation.
- 6) SMART module for LRM collision avoidance using virtual WHAP sensors and model-based collision avoidance while driving LRM simulation.
- 7) Teleoperations of LRM simulation with automatic collision avoidance.
- 8) Cost/benefit analysis model for operations of LRM in HLW tank coupled to simulation of operations in tank.
- 9) Rapid world model building with laser scanning.
- 10) VCE demo of operating NIST mill from SNL over network connection.
- 11) WHAP collision avoidance skin for robots (Merritt Systems CRADA product).
- 12) GENISAS-Orbix demo on 3 platforms: Sun OS, SGI IRIX and Windows NT (key to cheap VCE connections).

ORNL demo:

- 13) Remote demo of flexure controls on Schilling testbed over network connection.

PNL demos:

- 14) VCE demo of flexure control on testbed robot over network connection.
- 15) Novel control of modified Stuart platform.

University demos:

- 16) Remote demo of SHARP (a system for telerobotic health assessment) over network connection.
- 17) Multi-sensor Analysis Program for Environmental Restoration (MAPER) to locate and characterize buried waste.

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**Office of Technology Development,
Robotics Technology Development Program Overview**

Linton W. Yarbrough, PhD., Robotics Program Manager, DOE



6th Annual Robotics Forum

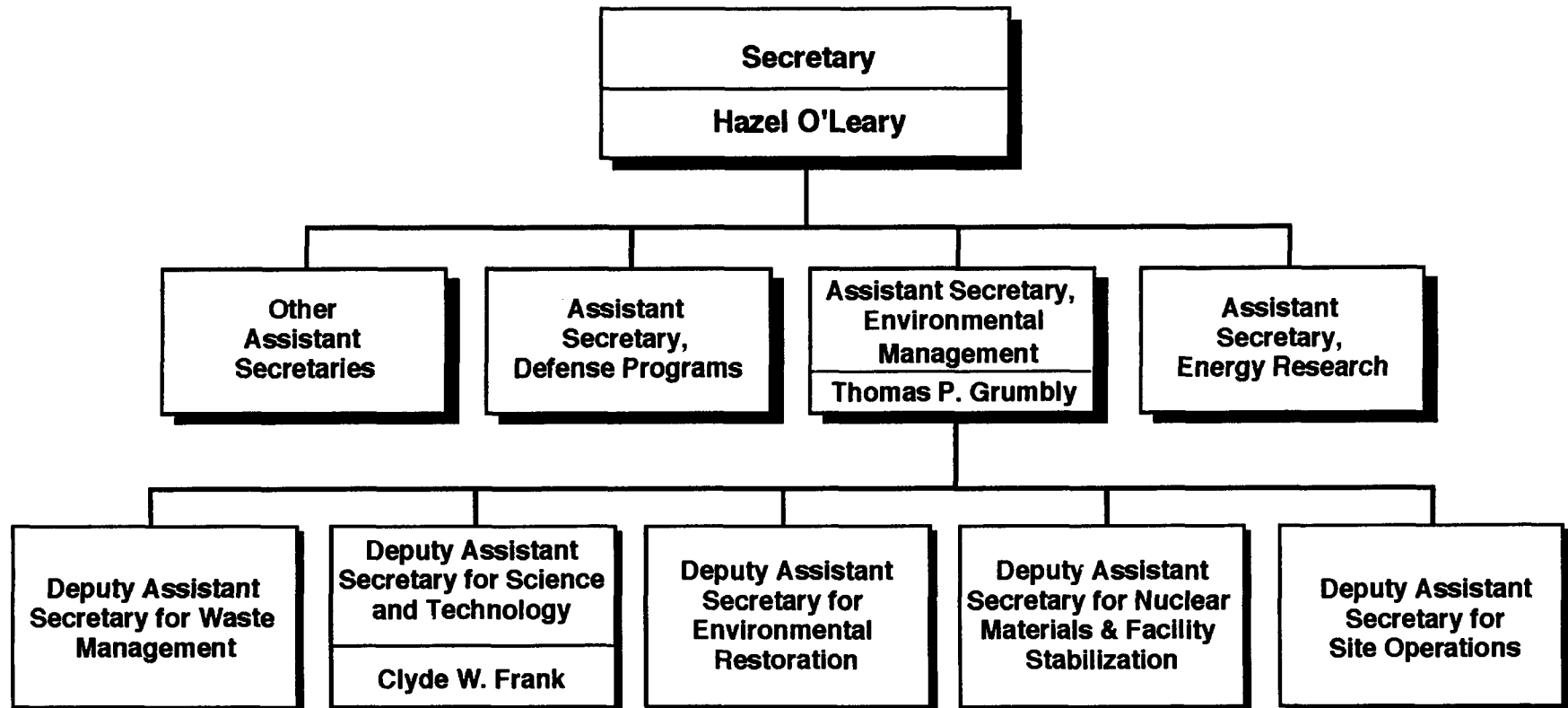
FY96 Robotics Technology Development Program

Linton W. Yarbrough, Ph.D.

August 16, 1995



U. S. Department of Energy





Office of Science and Technology Functional Organization

- **Focus Areas**
 - Combined EM-30, 40, 50, and 60 Management
 - Jointly managed by Headquarters and Field Offices
 - Headquarters provide oversight and broad programmatic direction
 - Field Offices provide management and implementation
- **Five Focus Areas**
 - Radioactive Tank Waste Remediation (Richland)
 - Mixed Waste Characterization, Treatment, and Disposal (Idaho Falls)
 - Decontamination and Decommissioning (Morgantown)
 - Landfill Stabilization (Savannah River)
 - Contaminant Plumes Containment and Remediation (Savannah River)



Office of Science and Technology Functional Organization

- Crosscutting Programs
 - Managed directly by Headquarters
- Three Crosscutting Programs
 - Characterization, Monitoring, and Sensor Technology
 - Efficient Separations and Processing
 - Robotics Technology Development Program

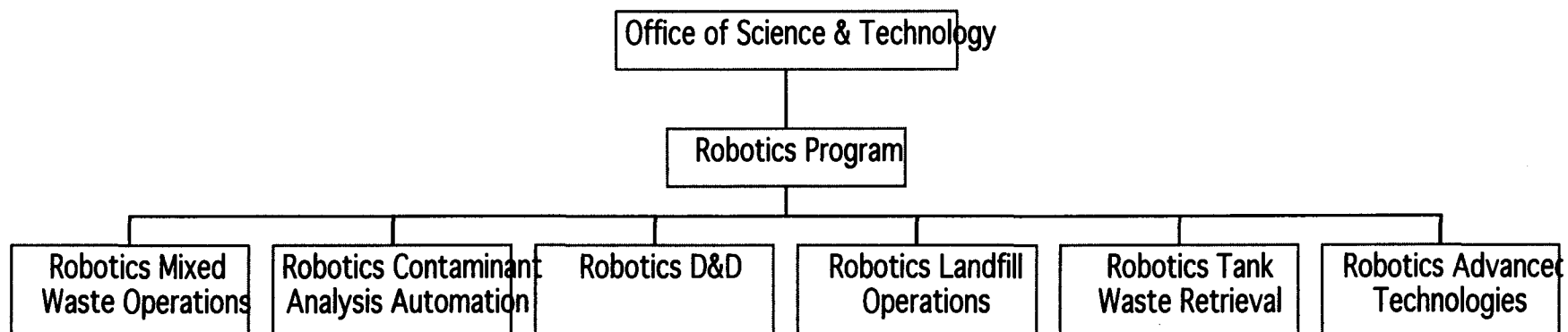


Robotics Technology Development Program Mission/Strategy

- **Problem**
 - Existing technologies are inadequate to meet EM's cleanup mission at a reasonable cost under proper worker safety conditions
- **Mission**
 - Develop robotic systems where justified by safety, cost, and/or efficiency arguments
 - Integrate the best talent from National Labs, industry, and universities into focused teams addressing complex-wide problems
 - Involve customers in the identification and development of needs driven technologies



Robotics Technology Development Program Organization





Robotics Technology Development Program Technical Application Areas

- **Mixed Waste Operations** - Automated system to remotely handle feed stock and output of plasma hearth treatment process and overall process controller
- **Contaminant Analysis Automation** - Automation of EPA analytical chemistry methodologies to reduce cost and processing time of DOE's large sample loads
- **Decontamination and Dismantlement** - Autonomous and teleoperated systems for surveillance, characterization and D&D of retired facilities
- **Landfill Operations** - Teleoperated systems for uncovering and opening buried waste containers
- **Tank Waste Retrieval** - Advanced controls for use on Oak Ridge LDUA
- **Advanced Technology** - Generic subsystems (control, sensor integration, etc.) applicable to multiple robotics projects



Robotics Technology Development Program Funding History

\$M	FY94	FY95	FY96
Mixed Waste Operations	4.0	2.7	3.9
Contaminant Analysis Automation	3.6	4.7	5.0
Decontamination & Dismantlement	3.6	4.9	7.2
Landfill Operations	0	0	1.4
Tank Waste Retrieval	4.9	4.7	0.8
Advanced Technologies	6.0	5.4	5.1
HQ Project	0	0	0.1
TOTAL FUNDING	22.1	22.4	23.6



Robotics Technology Development Program FY96 Budget Matrix (\$M)

Site	MWO	CAA	D&D	LFO	TWR	AT
SNL	X	X	X	X	X	X
ORNL	X	X	X		X	X
LANL		X				X
PNL	X	X	X		X	X
INEL	X	X	X	X		
SRTC	X		X	X		
LLNL	X		X			
FEMC			X			
TOTAL	3.9	5.0	7.2	1.4	0.8	5.1



Robotics Technology Development Program FY96 Performance Measures

- Demonstrate 7 technologies
- Make 2 technologies available for transfer
- Direct 50% of budget to private sector and universities

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Contaminant Analysis Automation

Robert M. Hollen, Contaminant Analysis Coordinator, Los Alamos National Lab



The integration of Science and Business

RTDP

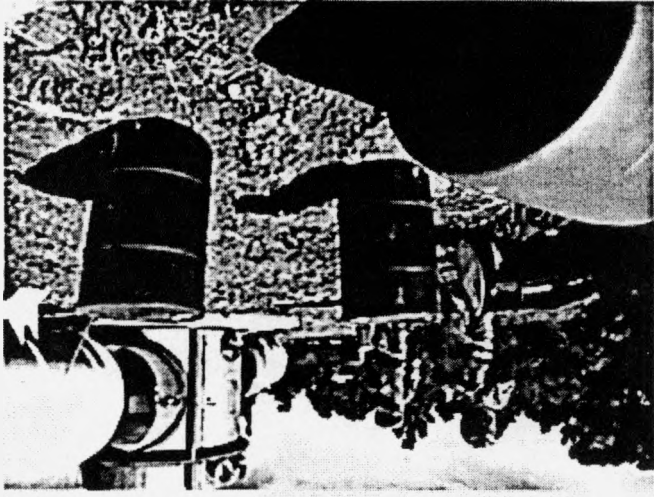
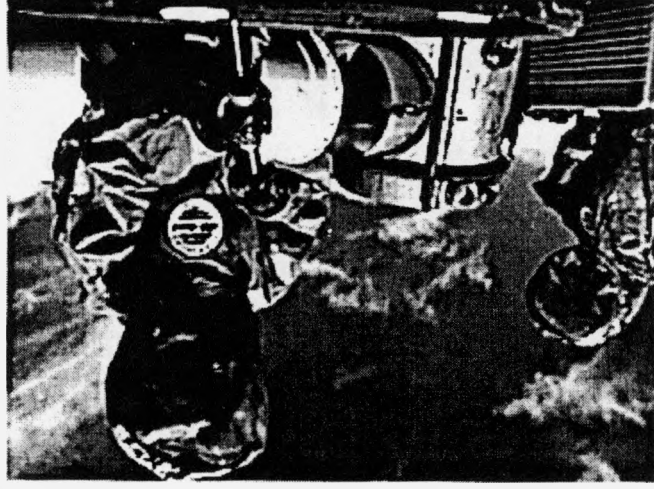
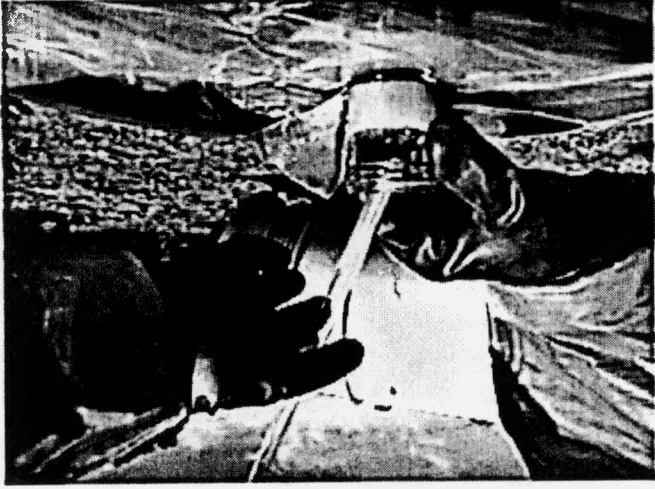
<http://eclipse.esa.lanl.gov/CAA-demo.html>

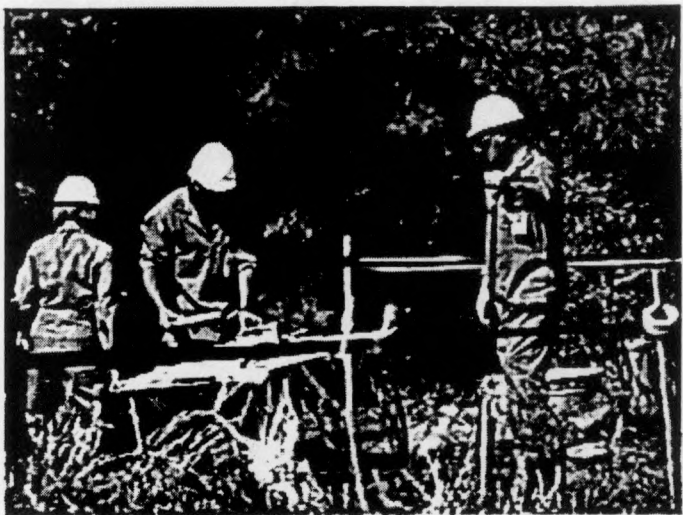
University Thrusts 1996

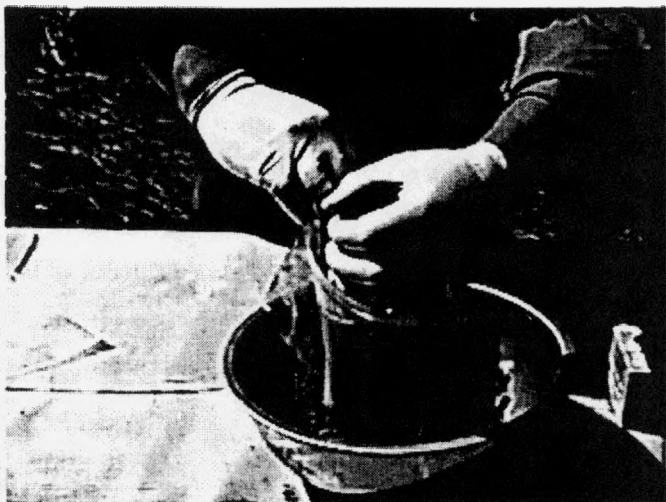
- Complete soil sample preparation SLM (Florida)
- HCI maintenance module (Florida)
- Gas Chromatography data processing and data fusion (Tenn)
- Begin advanced generic material handling system (Texas)

Major Thrusts for 1996

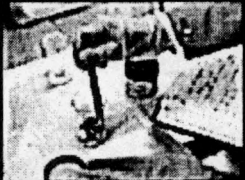
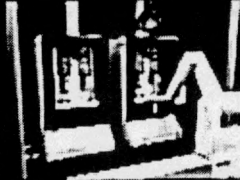
2. Beta testing of the Organic SAM System
 - Complete SLM construction
 - Complete system performance assessments
 - Chemically validate beta systems





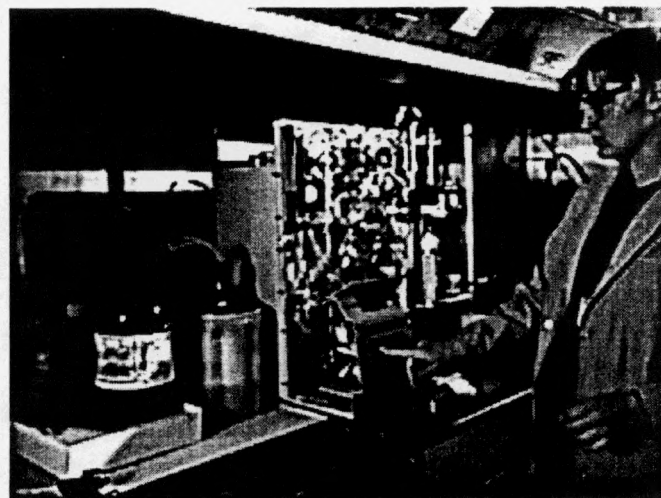


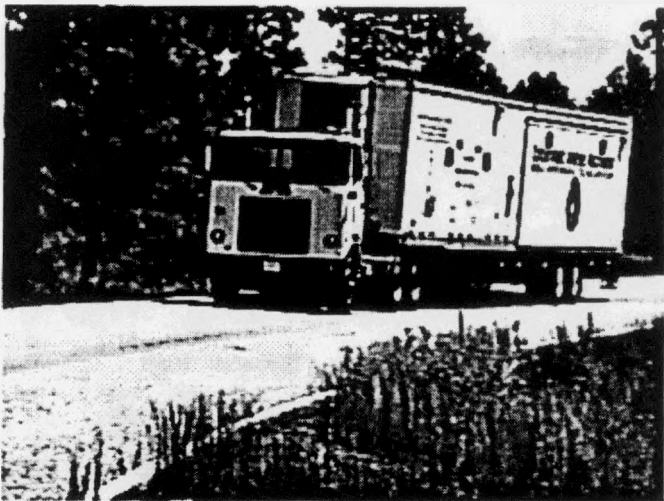
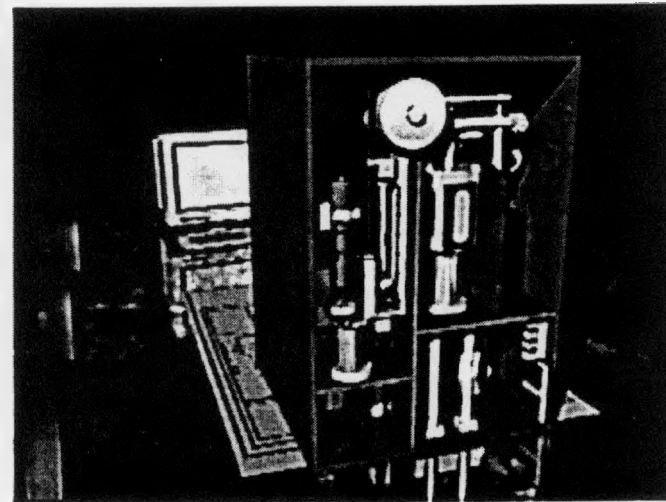
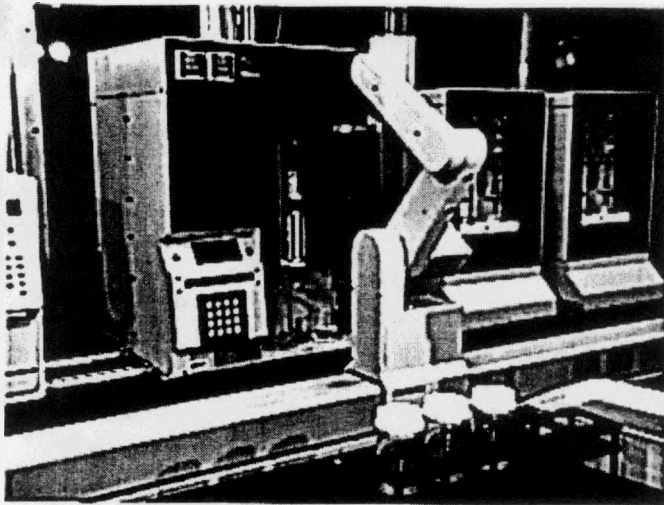
Cost Per Sample

Traditional Method	CAA Method
	
\$280.00	\$70.00

The Model Automated Lab

- Sample Log-In
- Continuous Sample Preparation and Analysis
- Data Package and Report Preparation



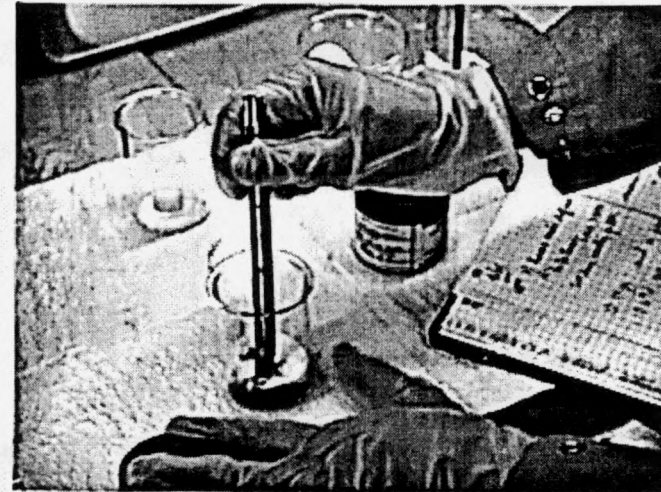


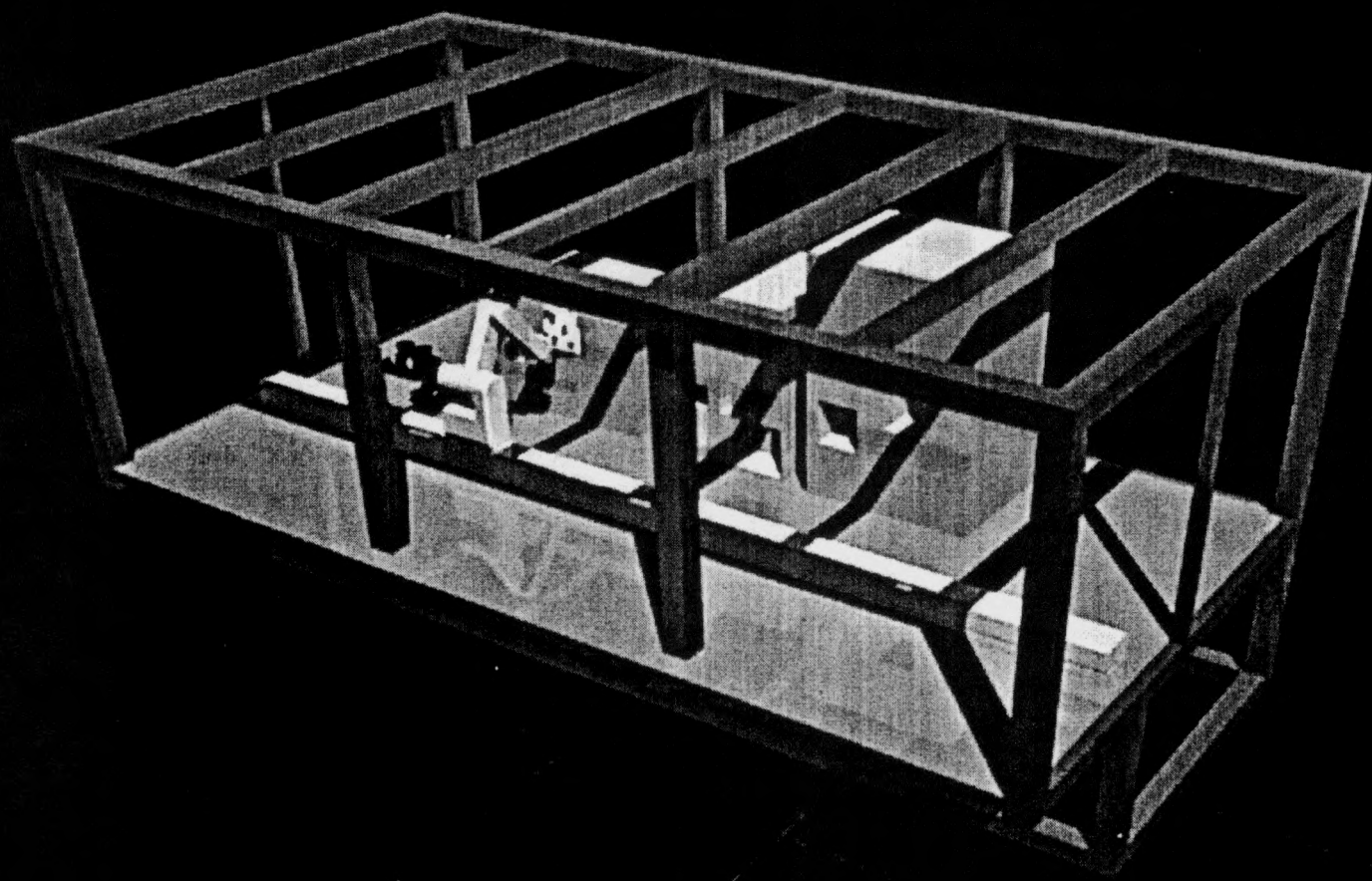
Comparisons

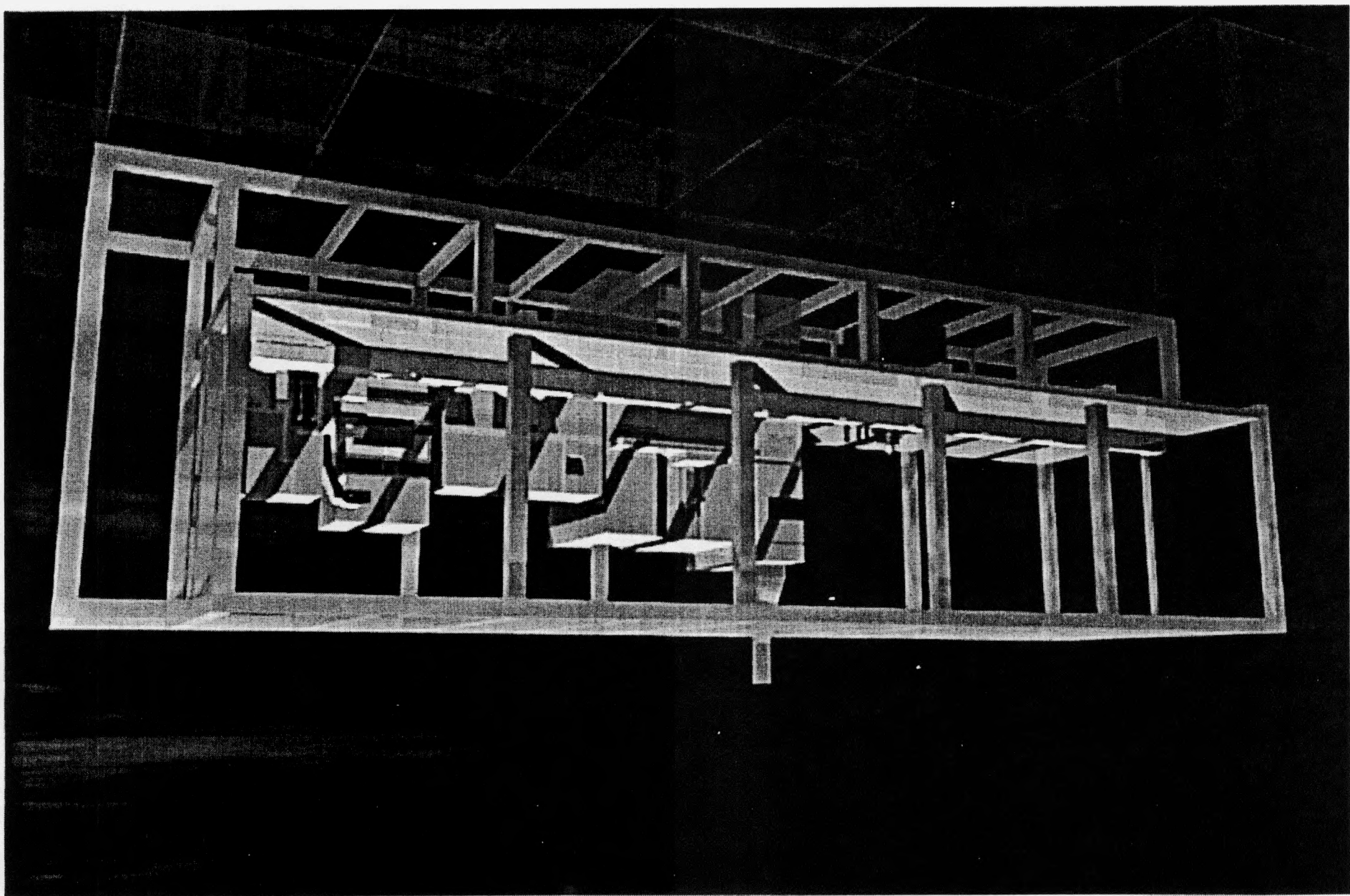
	CAA	Manual
Cost/Analysis	\$70	\$280
Precision	22%	25%
Throughput	32 samples	8 samples
Accuracy	54%	28% = EPA 70% = Lab
Waste Min.	85%	5%

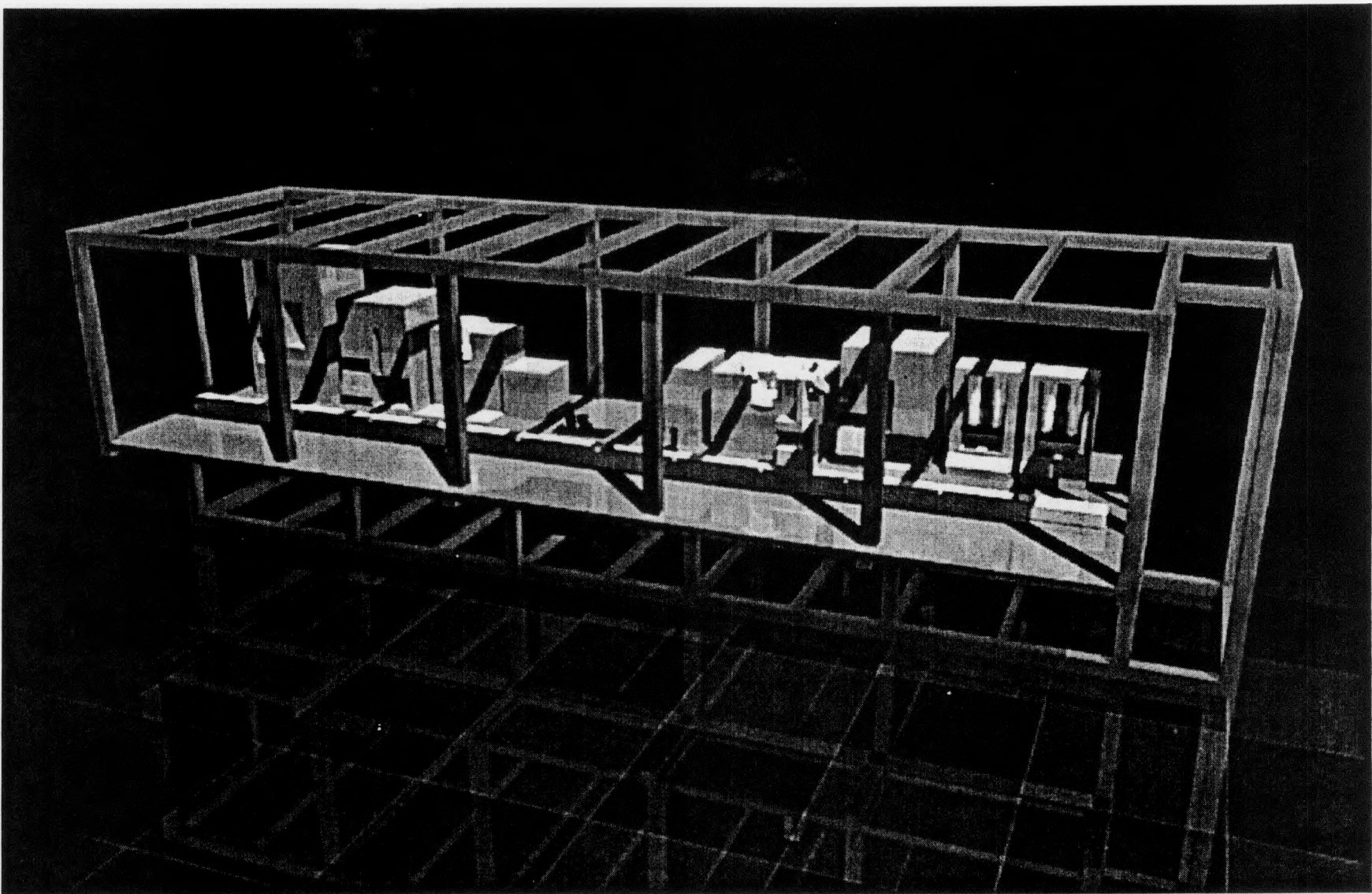
Savings

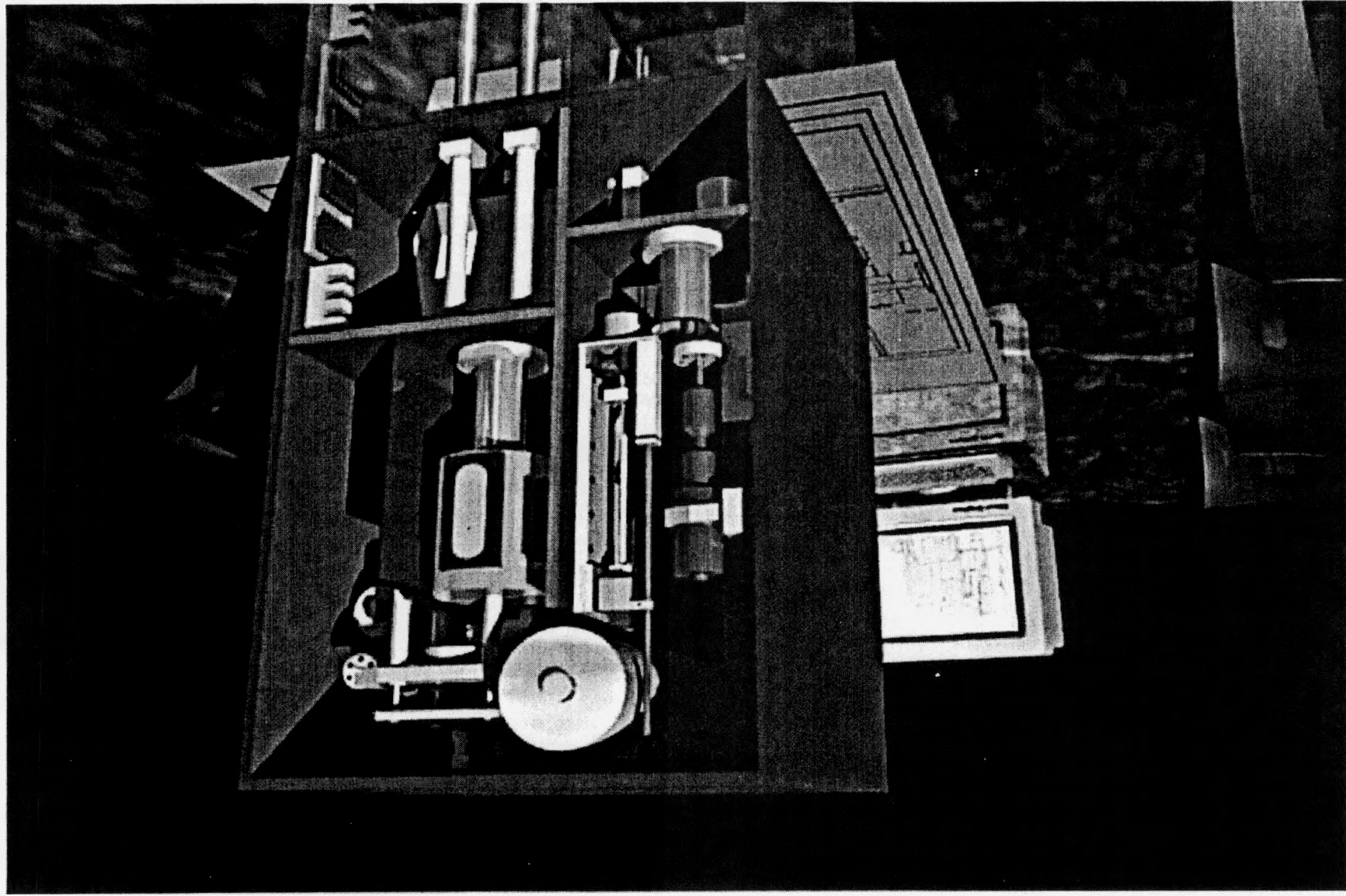
	CAA	Manual
Equipment	\$ 234,000	\$ 68,000
Labor	\$ 322,560	\$1,290,240
Total	\$ 556,560	\$1,358,240











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Decontamination and Decommissioning

**Bill Hamel, Decontamination and Dismantlement Assistant Coordinator,
Oak Ridge National Lab**

d
Robotics
Technology
Development
Program

DECONTAMINATION & DISMANTLEMENT ROBOTICS

Dr. William R. Hamel
D&D Robotics Coordinator

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6th Annual DOE/Industry/University Robotics Forum
Albuquerque, New Mexico
August 17-18, 1995

10/4/95

1

d Robotics Technology Development Program

OUTLINE:

1. INTRODUCTION

- » Team
- » Technical approach, and
- » Development philosophy

2. FY 95 STATUS

3. FY 96 PLANS

4. SUMMARY

ROBOTICS DECONTAMINATION & DISMANTLEMENT

d
Robotics
Technology
Development
Program

	<u>RTDP</u>	<u>URP</u>	<u>METC</u>
FY 96	\$7.29M	\$1.40M	\$12.2M
FY 95	\$4.63M	\$0.89M	
FY 94	\$4.31M		

RTDP D&D ROBOTICS TEAM

INDUSTRY:

Research Contracts:

Coleman Res*
 MTI*
 Oceaneering*
 JBF Assoc's
 etc.

Major Procurements:

Cybermotion
 Schilling Dev
 RedZone Robotics*

LABS:

ORNL-Lead
 SNL
 INEL
 PNL
 SRTC
 LLNL
 METC*
 NASA Langley

UNIVERSITIES:

CMU*
 U. of Tenn
 U. of Michigan
 U. of Texas
 VPI
 Washington
 St. Martin's College

*Major projects through METC

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Robotics
Technology
Development
Program

**FOCUS: Reduce Risk & Cost in the
Surveillance & Maintenance (S&M) Phase**

- **Phases:**
 - » **Operation/Shutdown**
 - » **De-Inventory**
 - » **Deactivation**
 - » **S&M: inactive standby status**
- **S&M Phase:**
 - » **Routine maintenance & security**
 - » **Escalating inspection & safety requirements**
- **Approach:**
 - » **Risk-based analysis methodology**
 - » **Reduce pre-S&M costs and disposition risk**
 - » **Automate continuing S&M functions**

d
Robotics
Technology
Development
Program

FOCUS: Systems and Technologies which . . .

- **Reduce Risk & Cost in Surveillance and Maintenance Phase of Facilities**
- **Meet D&D Focus Area objectives & support major demonstration goals**
- **Have clear connectivity to actual field projects**
- **Address higher risks while seeking practical commercialization**

d

Robotics

Technology

Development

Program

Technical Approach . . . Priorities

- Technologies that will impact current D&D projects including surveillance and maintenance costs and operations: cost reduction, safety enhancements, ALARA
- Technologies that can be rendered into believable demonstrations in 1 to 3 years
- Technologies that have broad applications to the total spectrum of D&D requirements
- Integrate with D&D Focus Area Management Team = Couple with EM-40 Projects

d
Robotics
Technology
Development
Program

Technical Approach . . . Philosophy

– Build from the foundation of classical remote operations:

- Effective teleoperations (human-in-the-loop) baseline
- Make remote operators better--not replace with computers
- Selective task-driven automation--human interaction
- Full automation (autonomous) operation for "simple" applications; repetitious tasks

– Amortize R&D across Equipment and Software Products:

- Modular and Reconfigurable
- Re-use across various characterization, decontamination, and dismantlement system concepts

– Evaluate new concepts: robotics & automation impact on productivity, safety and quality?

d Robotics Technology Development Program

D&D ROBOTICS: SIX MAJOR THRUSTS

- S&M Risk & Cost Reduction Evaluation

ORNL, SNL, SRTC, JBF

- Mapping, Characterization, and Inspection

- Facility Mapping System
- Mobile Automated Characterization System (MACS)

ORNL
UT
CMU
MTI
Coleman

- Selective Equipment Removal System

- Dual Arm Work Module
- Task Space Scene Analysis
- Transporters

ORNL
SRTC
Michigan
CYBERMOTION

- Small Pipe Characterization

- Internal Duct Characterization

INEL
INUKTUN

INEL
Foster Miller

ORNL
SNL
PNL
NASA LaRC
VPI
Tenn
Texas
Michigan
CMU
RedZone

- RTAF

ORNL, SNL, INEL

d
Robotics
Technology
Development
Program

**FY 95 RESULTS . . . Continue and finish-up,
one new start**

• **S&M RISK & COST REDUCTION
METHODOLOGIES**

- Finish methodology
- Apply to SRTC facility problem
- Transfer technology

• **Mapping, Characterization, and Inspection
Facility Mapping System**

- Remote image acquisition and model building needs
- Evaluate commercial capabilities - industry, software

MACS

- Complete systems integration
- Augment large area navigation system - Michigan
- Field demos at RMI, K-25
- Explore “reduced-access”
Characterization subsystem (satellite)

d
Robotics
Technology
Development
Program

FY 95 MAJOR THRUSTS . . . STATUS

- **Surveillance & Maintenance Risk & Cost Reduction Evaluation Methodologies**
 - » **Refined laptop software**
 - » **Application to SRTC**
- **Mapping, Characterization, and Inspection System**
 - » **Mobile Automated Characterization System (MACS)**
 - System up and running
 - RMI, K 25 Demo
 - » **Reduced Access Characterization System**
 - Procurement complete
 - » **Facility Mapping System**
 - Mobile, large scale mapping of physical geometry and contaminants
 - Focus on modeling and data (CAD) management issues
 - Evaluating existing software and commercial services

d

Robotics

Technology

Development

Program

40

FY 95 RESULTS . . . Continue and finish-up, one new start

• Selective Equipment Removal System

- Complete systems integration
- Upgrade operator control station
- Expand Task Space Scene Analyzer
- Add tooling & tooling controls
- Add supervisory control functions

New Hardware

- DAWM prototype positioner based on VGT
- ROSIE at RTAF Q4
- French Stabilized Crane Operation - commercially available

**Demonstrations in September (19-21)
at ORNL/RTAF**

d

Robotics

Technology

Development

Program

FY 95 RESULTS . . . Continue and finish-up, one new start

- **Small Pipe Characterization System**
- **Internal Duct Characterization System**

d

Robotics

Technology

Development

Program

FY 95 RESULTS . . . Continue and finish-up, one new start

- **D&D Robotics Technology
Assessment Facility**

- User facility for other labs,
industry, and universities
test and evaluate new D&D
robotic systems and tooling
- ORNL high bay facility
4000 sq. ft., 40 ft. clearance
OH transporter and 10T crane
- Realistic task mock-ups and
remote working conditions
- Systematic experimental
evaluations
- Infrastructure support
- Operational in Q2

d
Robotics
Technology
Development
Program

FY 96: TEST & EVALUATIONS

- **DECIDE . . . JBF Product**
- **MAPPING**
 - **EVALUATE TECH FEASIBILITY**
 - **“SIMPLE” PROTOTYPE with Coleman LADAR**
 - **MOBILE PLATFORM procurement**
- **CHARACTERIZATION**
 - **MACS in field doing demos**
 - **Integrated operation MACS/RACS**
 - **Finish IDCS, SPCS**
- **DISMANTLEMENT**
 - **SERS: OHT, CRANE, ROSIE**
 - **CP-5 Project: Systems for reactor vessel internals and biological shielding dismantlement – Joint EM 40 and 50 thru D&D Focus Area – major procurements**
 - **Full Scale Demos in RTAF: ROVER, CP-5 Support**

d

Robotics

Technology

Development

Program

D&D ROBOTICS SUMMARY

- fertile applications domain for robotics-related technologies
- both essential and beneficial in many D&D projects [wrt Life Cycle Costs]:
 - remote hi-rad operations
 - automation of inspection and repetition
- unified system approaches/designs will save money and reduce risk
- FY 95 efforts addressed T&E of systems, established a “real world” test facility, included SERS expansion into advanced control functions and MACS field evaluations.
- FY 96: GROWTH; Testing and Demos, new CP-15 Project with D&D Focus Area

d Robotics Technology Development Program

PHOTOS & FIGURES

- **RISK & C/B EVALUATION**
 - Decide Software
- **MAPPING**
 - RTAF with MACS, etc.
 - BRET Rack
 - RTAF
- **CHARACTERIZATION**
 - MACS
 - RACS
 - MACS/TRAILER
- **DISMANTLEMENT**
 - CARTOON
 - DAWM-IGRIP
 - SERS-IGRIP
 - DAWM
 - DAWM/OHT
 - ROSIE
- **RTAF**
 - RTAF (ROMD)
 - RTAF-IGRIP

d

Robotics

Technology

Development

Program

ADIOS

- **Hamel to Academia: University of Tennessee**
- **Haley to D&D Robotics Coordinator**
- **Thanks to all!**

Mixed Waste Operations

**Bruce M. Wilding, Mixed Waste Operations Coordinator,
Idaho Nuclear Engineering Lab**

RTDP Mixed Waste Operations

Bruce Wilding
Lockheed Martin Idaho Technologies



Office of Technology Development
Robotic Technology Development Program



Agenda

- **FY - 95 Accomplishments**
 - **SWAMI**
 - **Drum Handling**
- **FY - 96 Proposed Program**
 - **SWAMI**
 - **Funding**
 - **Joint MWFA Projects**

SWAMI

◆ Stored Waste Autonomous Mobile Inspector

Background

- ◆ Thousands of containers with radioactive, hazardous, and mixed waste at many DOE sites
- ◆ Waste containers:
 - 55, 85, and 105 gallon drums
 - B25 and white metal boxes
- ◆ RCRA requires periodic inspections of hazardous waste containers and storage facilities
- ◆ Robotic assisted inspection of waste containers
 - improved inspection and documentation
 - more efficient inspection

Program Phases

- Generic prototype development and demonstration (SWAMI I)
- Final system development (SWAMI II)
- System demonstration and testing at Fernald
- Technology transfer to industry

SWAMI I

- ♦ Fixed sensor
- ♦ Up to 3 levels high
- ♦ Short range position determination
- ♦ Gas proportional radiation detectors (2)
- ♦ Image transfer by optical disk

SWAMI II

- ◆ Articulated, motorized sensor platform
- ◆ Structured light system for dents and blisters
- ◆ Up to 4 levels high
- ◆ Scintillation radiation detectors (5)
- ◆ Image transfer over radio ethernet
- ◆ Image and surface analysis
- ◆ Automatic battery charger
- ◆ Backing navigation and collision avoidance

Team Responsibilities

- **Lawrence Livermore National Laboratory**
 - Image analysis (rust spots and streaks)
 - GISC, same look and feel as the rest of the user interface
 - Geometric inspection (dents and blisters)
 - Report generation
- **Fernald Environmental Management Project**
 - Facilities and operators for test, test plan
 - Interface to site database, archival storage

Team Responsibilities Cont.

- ◆ Savannah River Technology Center
 - Vehicle development
 - Programming
 - Bar coding
 - Radiation detection system
 - Interface to Fernald data base
 - Image collection and structured lighting system
 - Controls and sensors

Project Constraints (at Fernald)

- ◆ 55 and 85 gallon drums - up to 4 levels high
- ◆ Dead end aisles, 36 inches wide
- ◆ Containment curbs, ramps and floor grates
- ◆ Significant inventory turnover
- ◆ No temperature control
- ◆ Each container uniquely bar coded
- ◆ Several large capacity facilities - up to 12,000 drums

Rust Spot & Streak Detection

- (2) CCD video cameras and (2) light strobes per platform
- Frame grabber captures images
- Compression algorithm
- Additional data added (drum no., pos., time)
- Onboard hard disk storage
- Compressed Image sent over radio ethernet
- Image analysis on Datacube hardware
- Anomalies reported to inspector with highlighted image

Dent & Blister Detection

- (3) CCD video b&w cameras and (2) laser stripers per platform
- Frame grabber captures images
- Real time range data extraction
- additional data added (drum no., pos., time)
- Onboard hard disk storage
- Range data sent over radio ethernet
- Feature (line) extraction on Datacube hardware
- Anomalies reported to inspector with highlighted line images of drum surface

SWAMI Operator Interface

- ♦ RAD MAP
- ♦ Base vehicle
- ♦ On-board control computers
- ♦ Position determination
- ♦ Bar code scanners
- ♦ Rust spot streak detector
- ♦ Dent & blister detection
- ♦ Inventory reporting

SWAMI Objectives and Benefits

- Reduce personal hazards and exposure
- Increase cost effectiveness
- Improve inspection data quality and documentation
- Enhance waste management operations
- Prevent containment failure

Schedule

- August 22: Final integration testing at SRTC
- September 11: Ship to Fernald
- September 17: SWAMI pre-evaluation testing
- September 18: Start formal testing

Drum Inspection Vehicle Bake Off

- Funded by MWFA
- METC : ARIES and IMSS system
- RTDP : SWAMI
- Scheduled for August of 1996

FY - 96 RTDP Program

- ◆ Refine SWAMI for bake off
- ◆ Support Plasma Hearth Furnace development

Plasma Hearth Program

- ◆ Over 1,000,000 drum of mixed waste at DOE facilities
- ◆ Lack of clearly defined waste disposal criteria
- ◆ Lack of proven mixed waste treatment capability
- ◆ Characterization requirements increase the cost and safety risks

Plasma Hearth Program Cont.

- ◆ Minimize process steps to achieve final waste form
- ◆ Treat waste without opening the drum and sorting contents
- ◆ Process a wide variety of waste streams
- ◆ Reduce characterization required and subsequent cost and risk
- ◆ Provide stable waste form that will meet all regulatory requirements
- ◆ Provide maximum volume reduction
- ◆ Simple design to reduce operating and maintenance problems

Technical background

- ◆ Plasma Hearth Process (PHP) is a thermal technology to treat alpha contaminated, CH-TRU, or LLW
- ◆ The technology uses a DC arc generated plasma
- ◆ Operates in the transferred arc mode
- ◆ Uses flow of gas to stabilize an electrical discharge between a high voltage electrode and a molten pool of waste. Plasma gas temperatures are estimated to reach as high as 10,000 C.

Four Phases of PHP Development

- ◆ **Proof-of-Principle**

- **Non-radioactive**
- **Near full scale (fed 3-gallon drums)**
- **Done to show feasibility of processing a wide variety of waste using PHP**
- **Tests conducted in California in 1993 and 1994**

- ◆ **Radioactive Bench Scale**

- **Small scale (fed 1-gallon paint cans of waste)**
- **Being built at ANL-W TREAT facility**
- **Capable of testing on TRU waste**
- **Testing to commence in December, 1995**

Four Phases of PHP Development Cont.

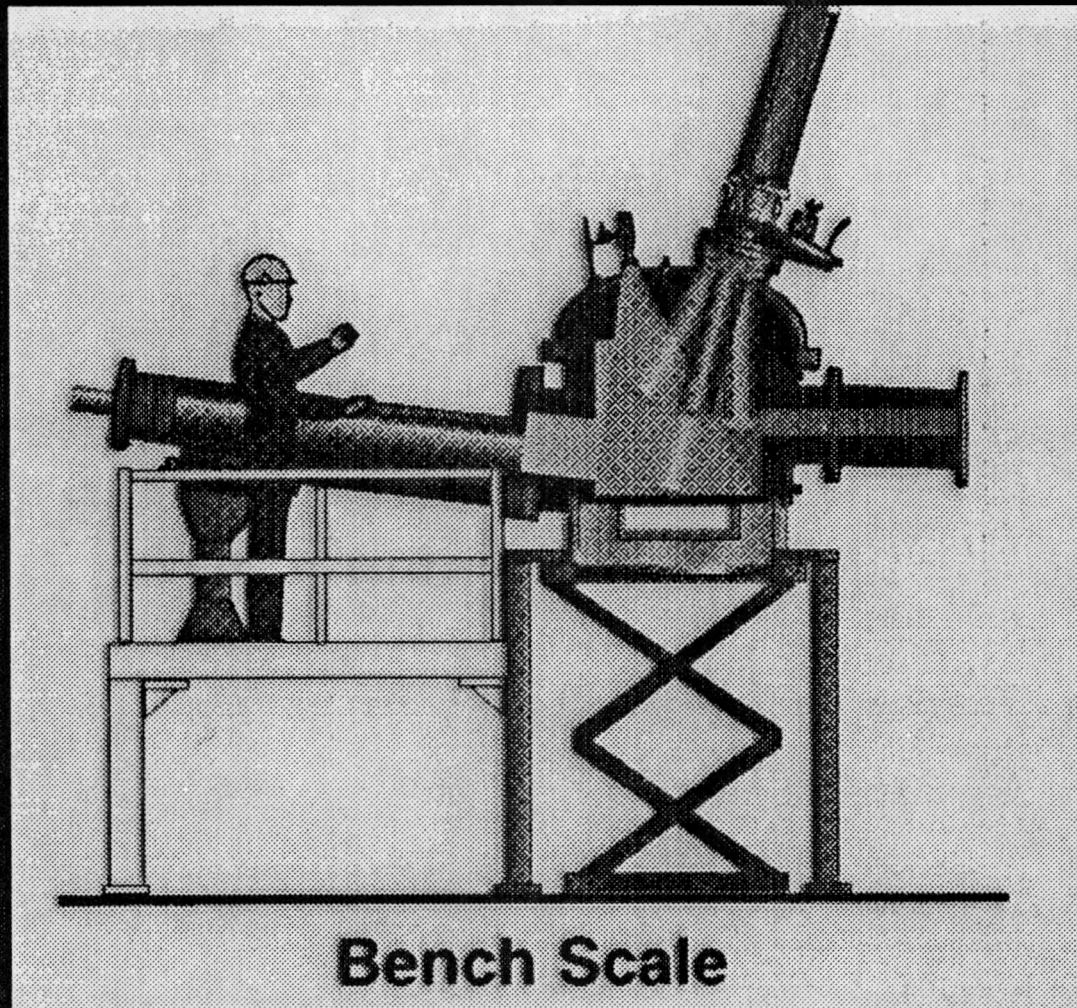
◆ Non-radioactive Pilot Scale

- Extension of Proof-of-Principle tests
- Provides engineering data for full scale operation
- Tests to be conducted in California in 1995-1996
- Fed 55-gallon drums

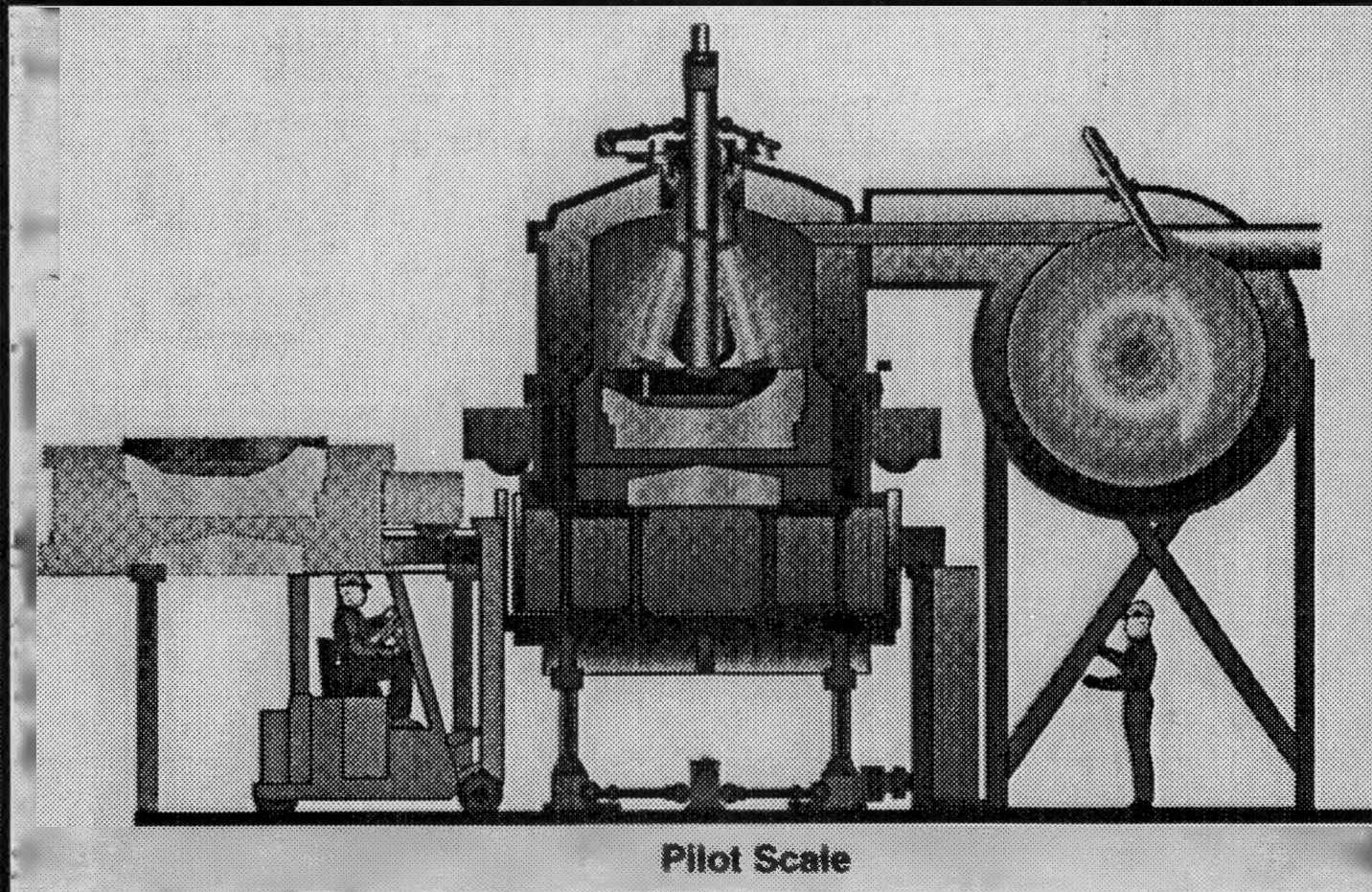
◆ Radioactive Field Scale

- Same size as pilot scale
- Demonstrate ability to process rad-waste on a full scale system
- Capable of processing TRU waste
- Tests to commence in the fall of 1997

PHP Radioactive Bench Scale



PHP Non-radioactive Pilot Scale



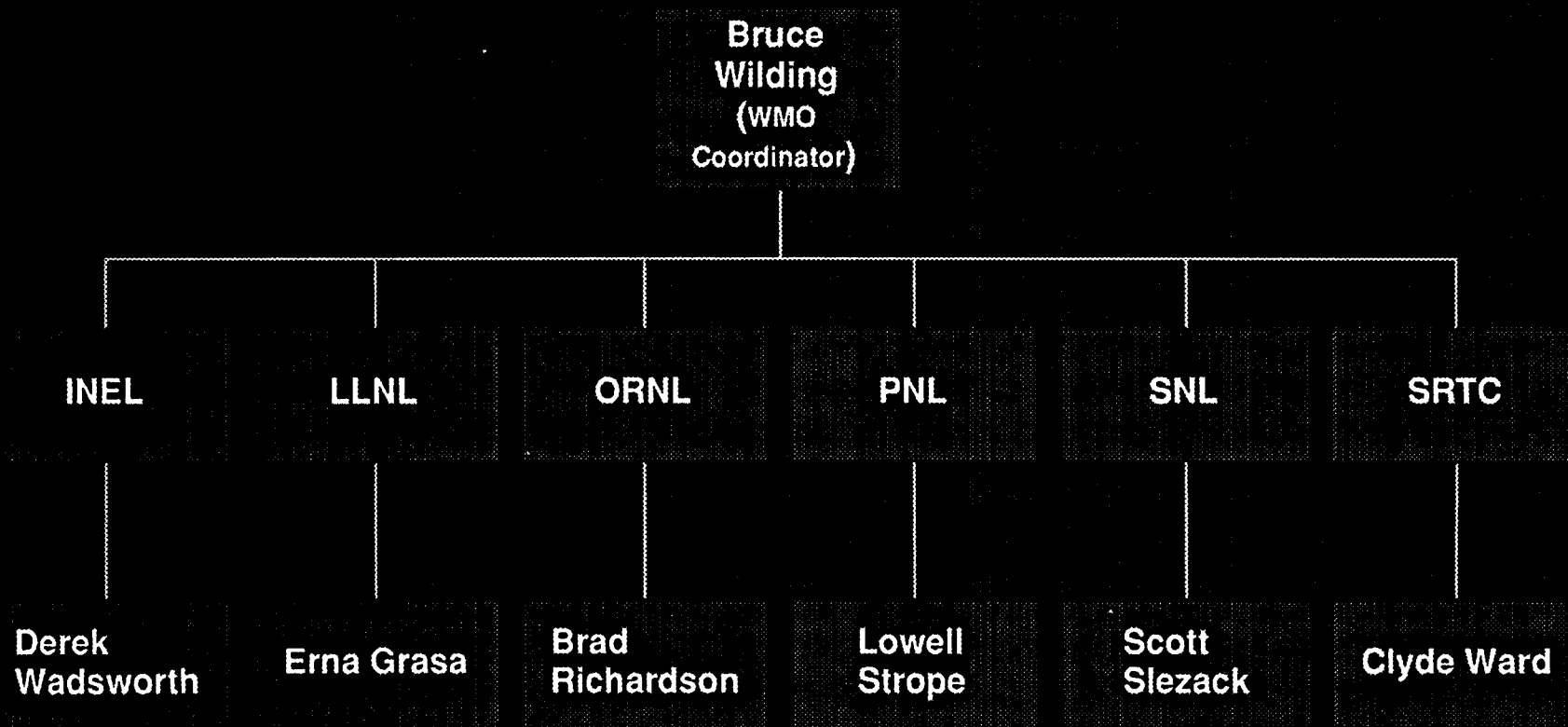
RTDP Mixed Waste Operations

Robotics Forum 1995

Organizational Responsibilities

- ♦ LMIT - Project coordination, equipment procurement, technical oversight
- ♦ SAIC - Engineering and technology development, permit writing
- ♦ ANL-W - Providing TREAT facility, facility modifications, permit submission
- ♦ DOE-ID (EM-50) - Funds management, technical and program oversight
- ♦ Retech - Torch and hearth manufacture, Pilot Scale test operations

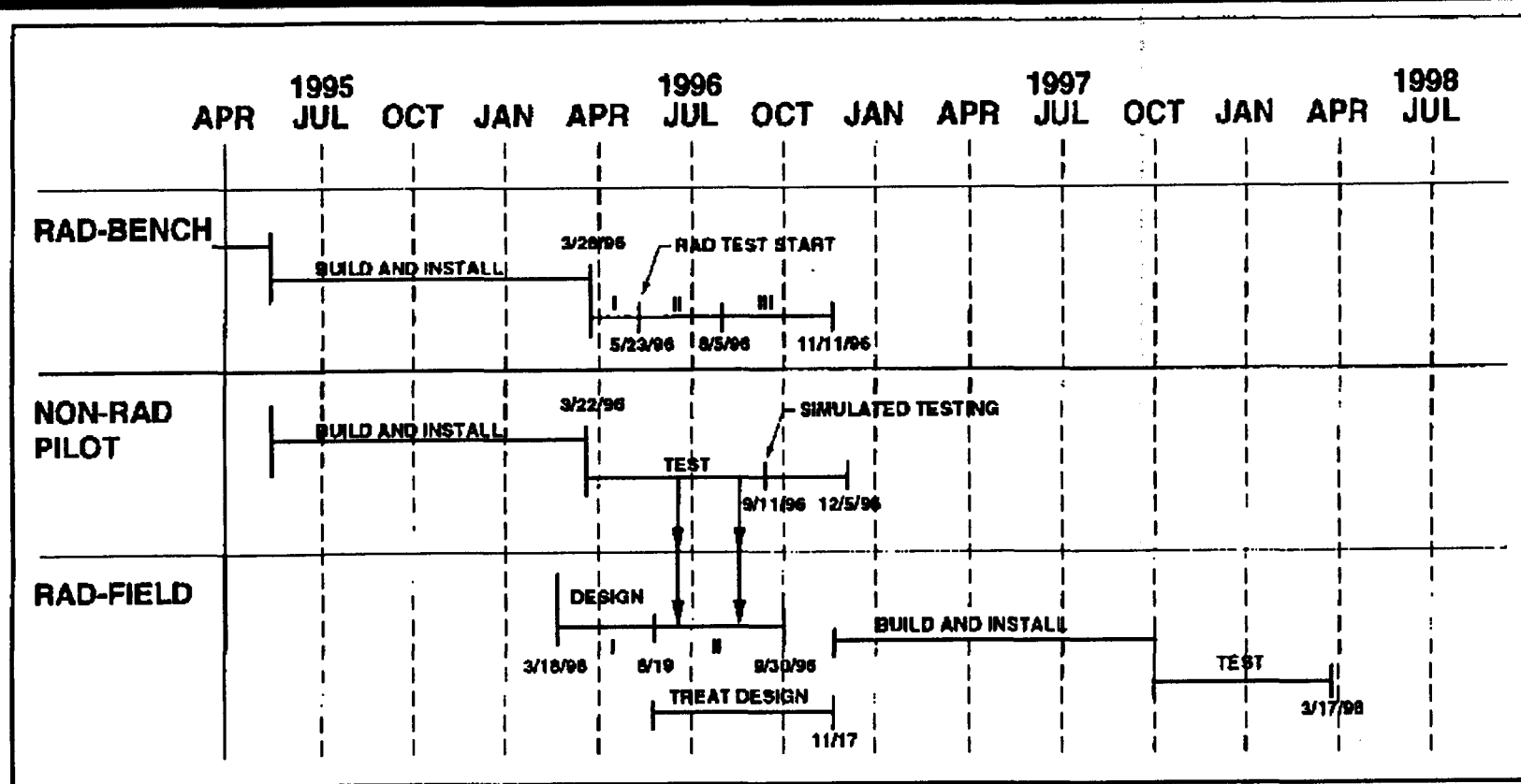
MWO RTDP Team



RTDP Mixed Waste Operations

Robotics Forum 1995

Plasma Hearth Process Demonstration Schedule



Funding Summary

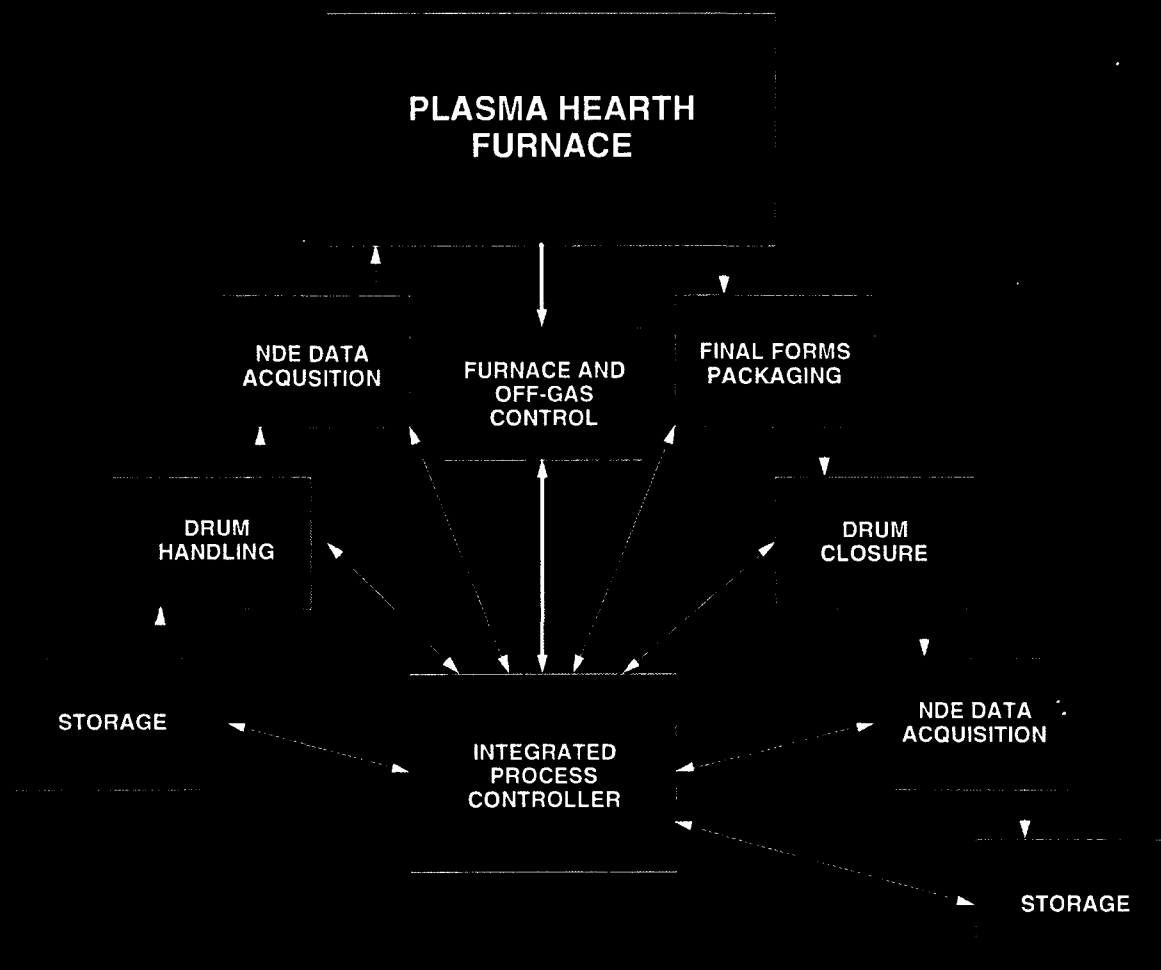
Funding Source	Operating Funds	Capital Funds
RTDP	\$ 3,410 K	\$ 530 K
MWFA	\$ 315 K	\$ 665 K
University	\$ 650 K	

RTDP Mixed Waste Operations

FY-96 RTDP MWO Tasks Summary

- Refine SWAMI for bake-off
- Final Forms Packaging
- Drum Closure
- NDE Data Acquisition
- Plasma Hearth Integrated Controller

FY-96 PHP Support



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Landfills Operations

**Clyde R. Ward, Landfills Operations Coordinator,
Westinghouse Savannah River Company**

**Robotics Forum
8/16/95
Landfill Operations Robotics**

OTD RTDP

**Landfill Operations
Robotics
FY96**

**Technical Coordinator
Clyde Ward**

LandFill Operations

1

OTD RTDP

Background

- FY96 first year for Landfill Operations Robotics
- Tasks aligned with Landfill Stabilization Focus Area
 - assessment/characterization
 - containment (barriers, caps)
 - stabilization (in situ)
 - retrieval
 - treatment
 - disposal

LandFill Operations

2

Clyde R. Ward, SRTC

Robotics Forum 8/16/95 Landfill Operations Robotics

OTD RTDP Major Thrusts

- Non-destructive drum opening
- Characterization and monitoring earthworm

LandFill Operations

3

OTD RTDP Reason for Drum Opening

- Material removed for treatment other than plasma hearth
vitrification
acid digestion
- Non-destructive opening of 55 gallons drums
drums and lids to be recycled for treated waste
lid clamping ring & bolt may be destroyed
- Demo site - SRTC

LandFill Operations

4

Clyde R. Ward, SRTC

Robotics Forum
8/16/95
Landfill Operations Robotics

OTD RTDP

Drum Opening Subsystems

- Swing-free crane modification and drum lifting tool
- Drum chuck (clamping and rotation)
- Industrial robot
- End effectors
- Teleoperation, programming, integration and testing

LandFill Operations

5

OTD RTDP

Industrial Involvement

- Swing-free crane modification
- Crane-hung drum lifting mechanism
- Industrial robot
 - 50 - 100 lb. capacity
 - capable of teleoperation
- End effectors
 - cut lid clamping ring bolt and remove clamping ring
 - remove lid
 - cut and remove liner top

LandFill Operations

6

Clyde R. Ward, SRTC

**Robotics Forum
8/16/95
Landfill Operations Robotics**

OTD RTDP

Reason for Earthworm

- Provide platform for underground characterization & monitoring
- Turn tight corners (~2' radius) to go under containers/tanks
- Capture samples and deploy sensors
- Demo at INEL cold test area
- Demo under actual buried tanks at INEL

LandFill Operations

7

OTD RTDP

Earthworm Subsystems

- Impact head
- Hydraulic steering system
- Cable drive bellows system
- Hydraulic-power unit
- Teleoperated control
- Tracking system

LandFill Operations

8

Clyde R. Ward, SRTC

**Robotics Forum
8/16/95
Landfill Operations Robotics**

OTD RTDP

Industrial Involvement

- CRADA for tracking system
- Underground vibration equipment
- Sensor systems, similar to penetrometer (VOCs, etc.)

LandFill Operations

Clyde R. Ward, SRTC

Tank Waste Retrieval

Barry Burks, Tank Waste Retrieval Coordinator, Oak Ridge National Lab

**ROBOTICS TECHNOLOGY
FOR TANK WASTE RETRIEVAL
FY 1995 ACCOMPLISHMENTS AND FY 1996 PLANS**

**Dr. Barry L. Burks
Oak Ridge National Laboratory**

RTDP Tank Waste Retrieval Coordinator

August 16, 1995

TWR Objectives

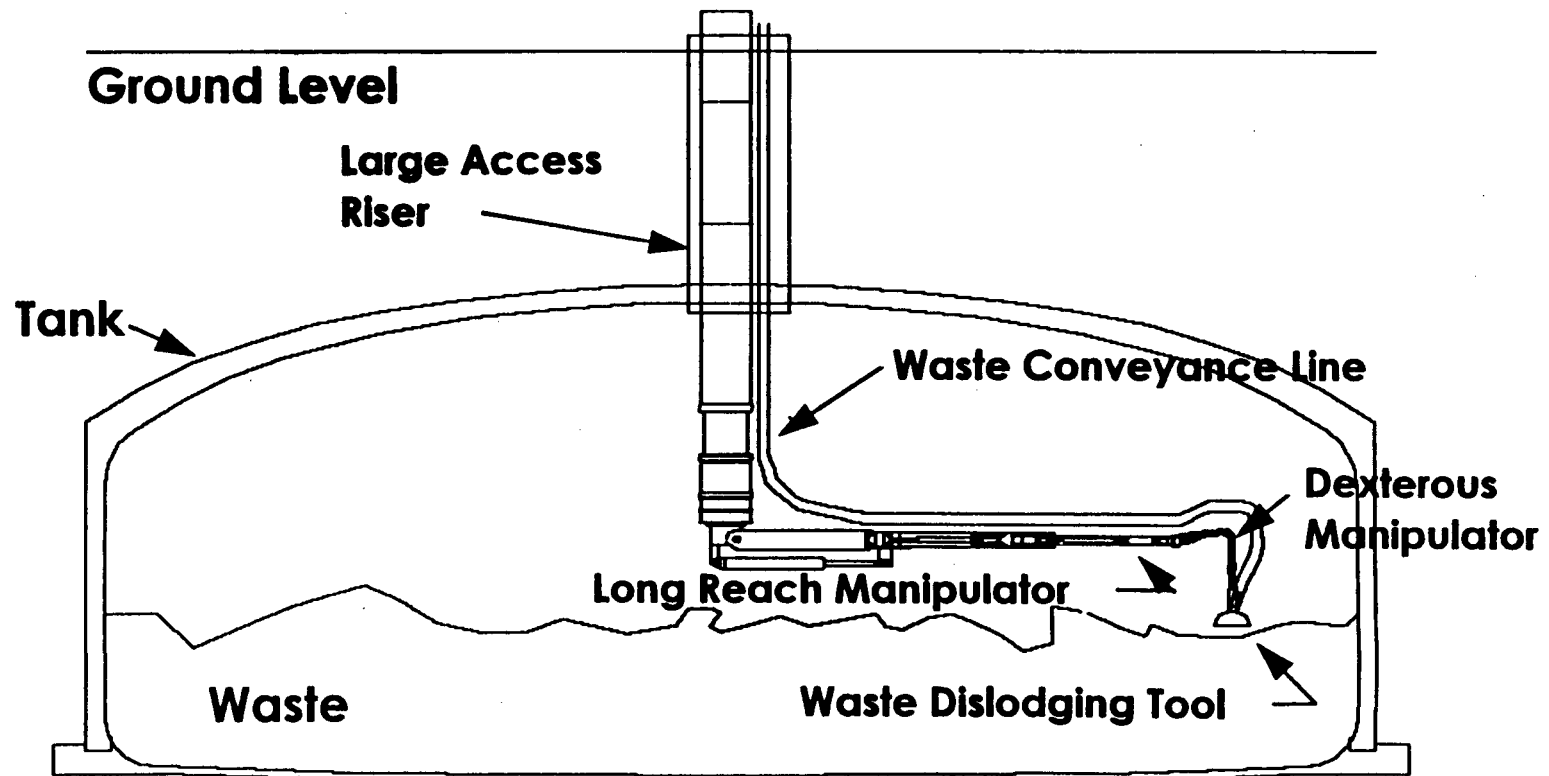
- **Provide performance baseline for manipulator-based retrieval systems and components.**
- **Provide specific retrieval solutions and methods addressing practical needs.**
- **Provide design and evaluation tools.**
- **Provide effective and aggressive technology transfer**
 - from RTDP to private sector,
 - from RTDP to EM-30 and EM-40
 - from RTDP to other EM-50 programs
 - from RTDP to other Federal programs.

TWR USER INTEGRATION

- **Biggest potential payback for robotics TWR technology development is remediation of Hanford Single-Shell Tanks (SSTs).**
 - From 1990 through 1995 the primary focus of TWR activities centered on Hanford SST retrieval requirements.
 - Applications at other sites also addressed.
- **Near-term opportunities for application of robotics TWR technology are at ORNL and Fernald.**
 - Manipulator-based retrieval at ORNL Gunit tanks
 - Vehicle-based retrieval at ORNL and Fernald K-65 Silos

ROBOTICS
Tank Waste
Retrieval

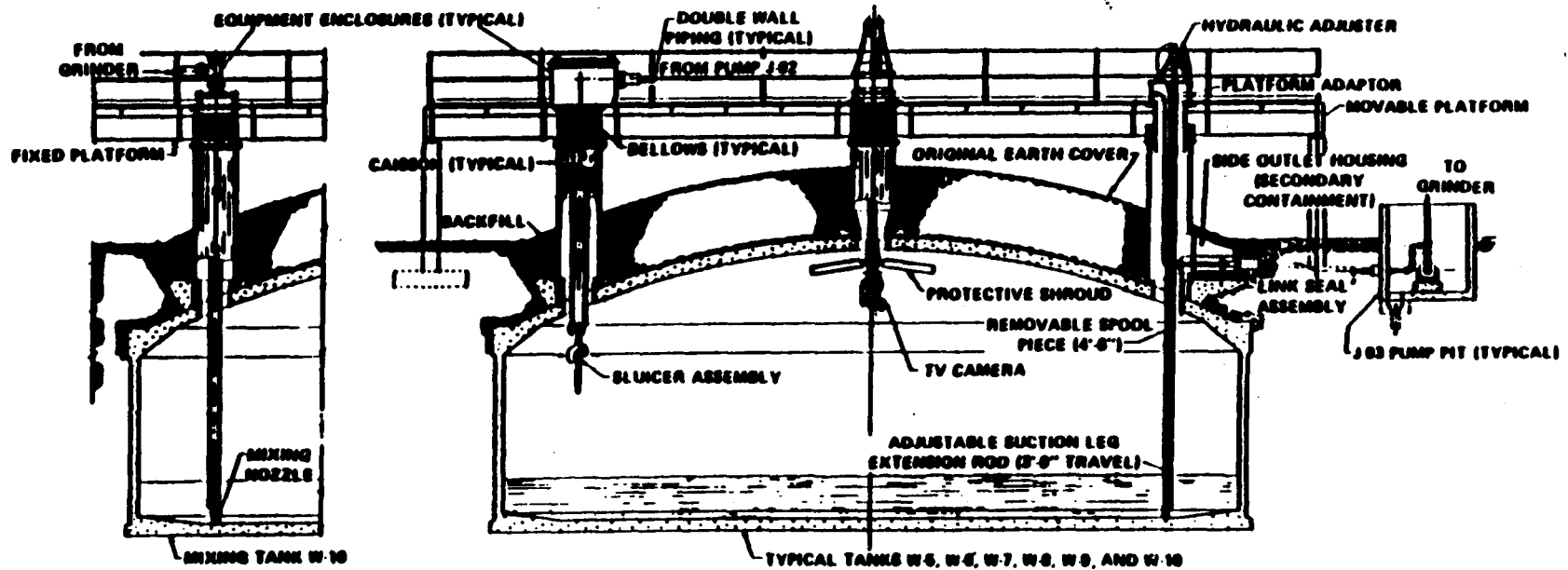
Manipulator-Based Retrieval Concept



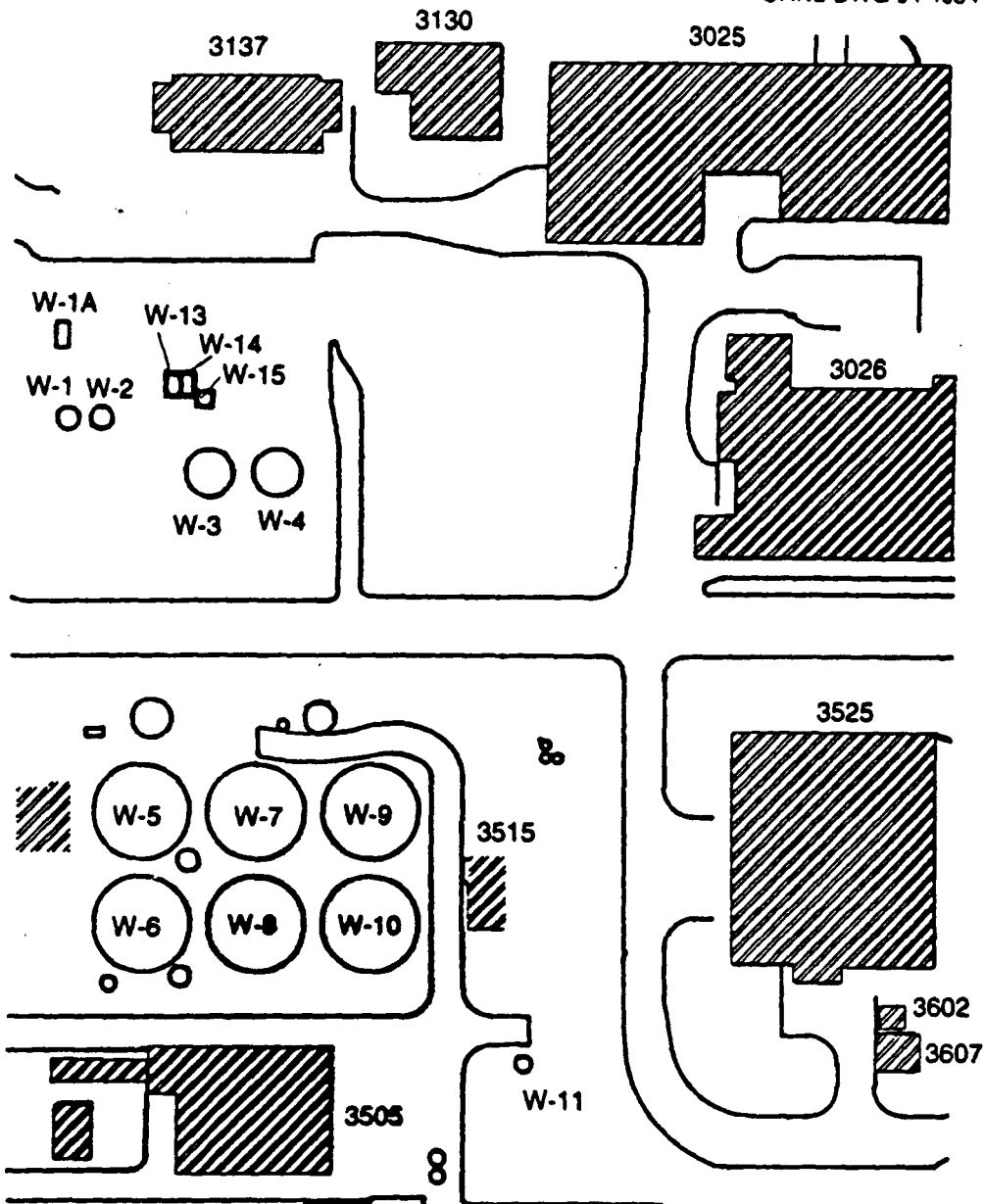
Cross-section of Gunite Tank During Operations in 1984

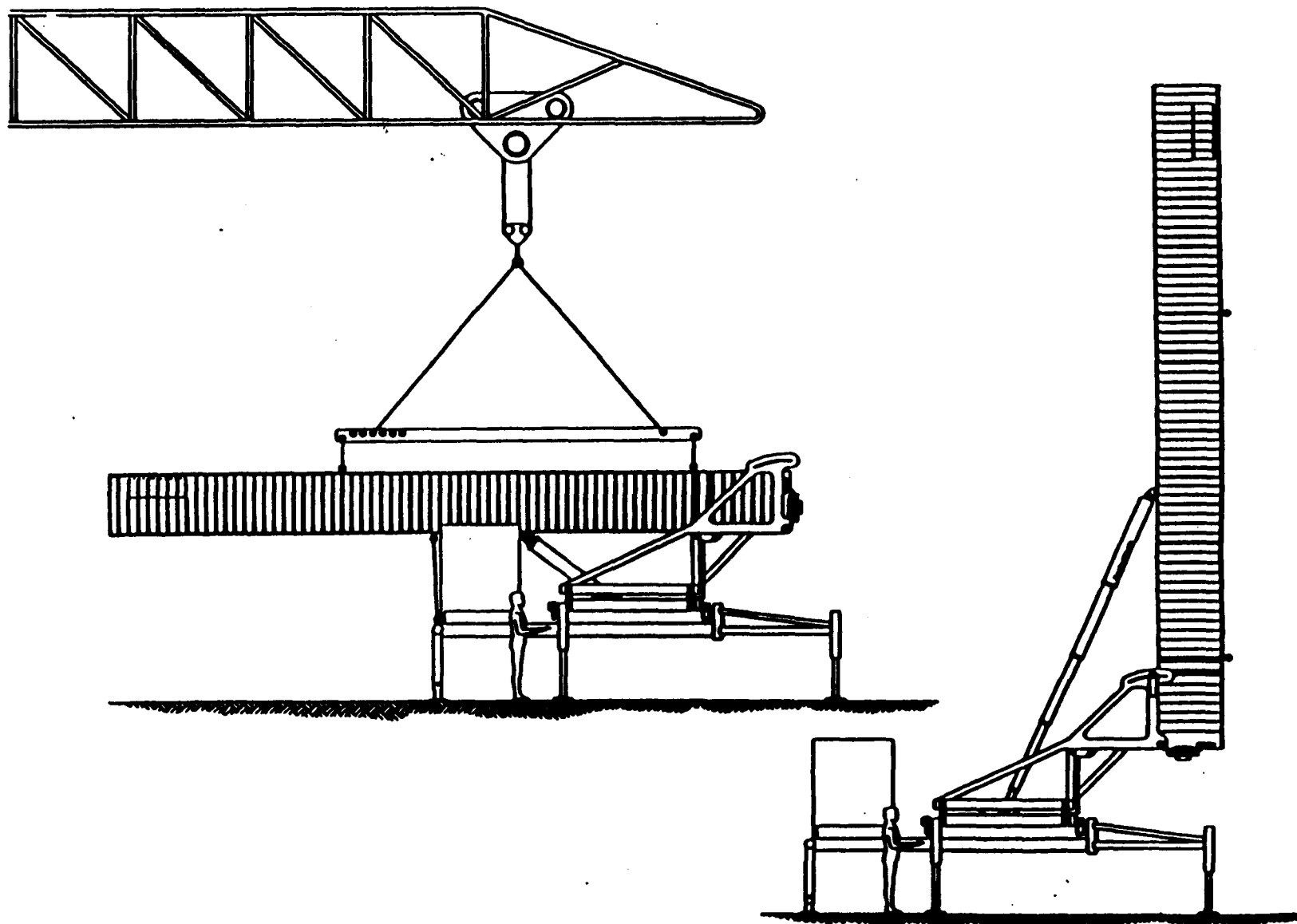
DWR, NO. 1, 1/8-80-1000

06



MARTIN MARIETTA





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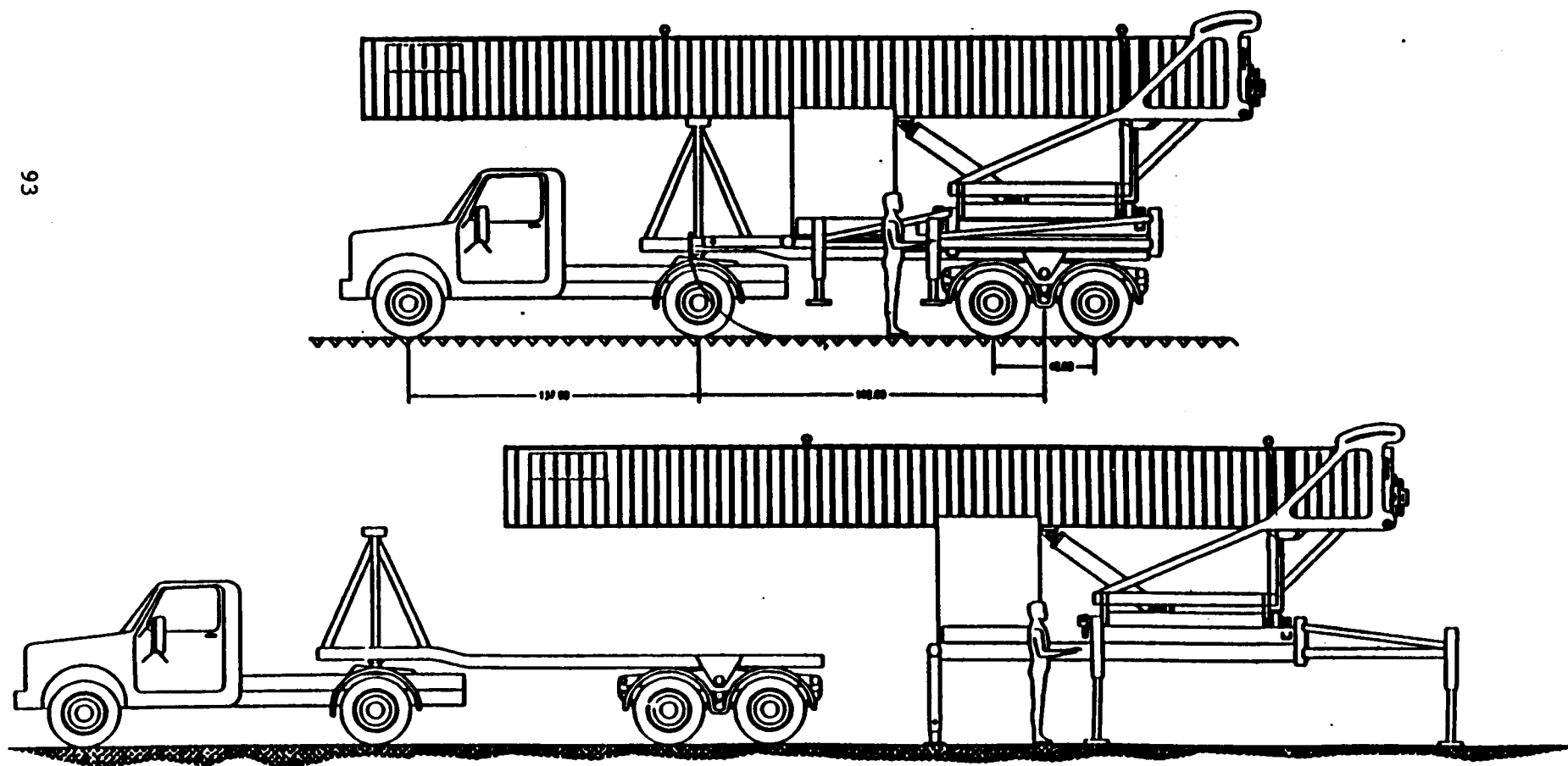
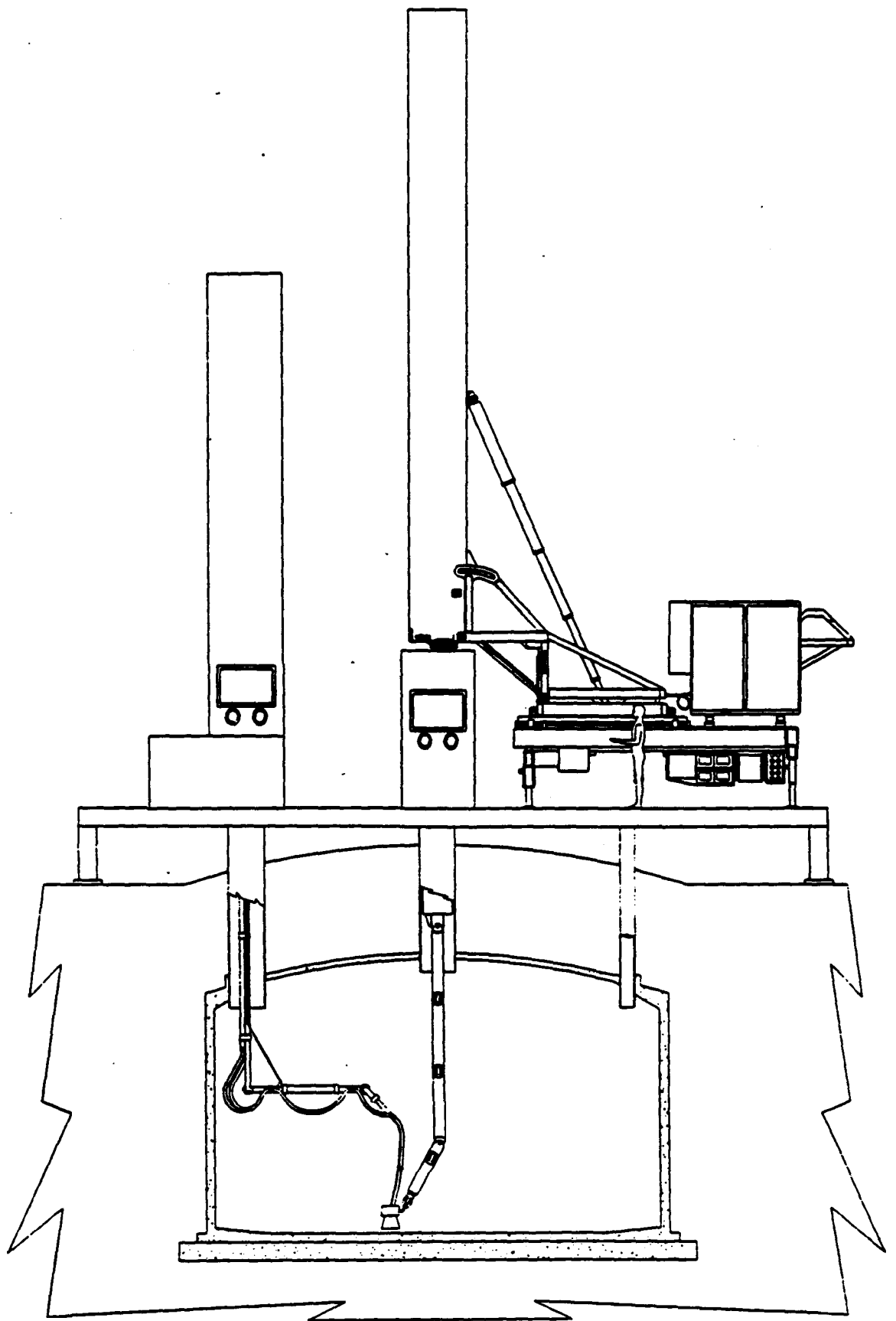


Figure 3-5 De-Mountable Fifth-Wheel Trailer Concept



TWR DEVELOPMENT AGENDA

- **Long reach & dexterous manipulation**
- **Manipulator controls**
- **Supervisory control & safety systems**
- **Human machine interface & productivity**
- **Tank & waste mapping**
- **Modeling & simulation for design evaluation**
- **Manipulator end-effector tools**

FY 1995 TWR HIGHLIGHTS

- **Long reach & dexterous manipulation**
 - System procurement underway, positioned for a FY 1996 delivery of the full scale test bed manipulator
 - Procurement status now unclear
 - Design of test bed and control station completed
 - Development & demo of modeling and simulation tools

- **Manipulator Control**
 - Demos of flexible structure control
 - Multi-plane oscillation damping
 - High-speed network based control
 - Position and orientation tracking system developed

FY 1995 TWR HIGHLIGHTS (Cont)

- **Work Space Mapping**

- Task space mapping of both static and dynamic scenes
 - > Spar Laser Rangefinder (completed)
 - > Lockheed Fringe Projection System (completed)
 - > Jet Propulsion Laboratory Stereo Camera (completed)
 - > Mechanical Technology Incorporated Structured Light
 - > Coleman Research Coherent Laser Radar

- **Human Factors**

- Task analysis & productivity assessments based on simulated operator tests
- Cost/benefit analysis completed

TWR PARTICIPANTS

- **FY 1995**
 - **INEL, ORNL, PNL, SNL**
 - **University of Tennessee, University of Florida, Georgia Tech, Washington State University, Florida International University**
 - **Multiple vendors**

- **FY 1996**
 - **ORNL, PNL, SNL**
 - **Washington University, Florida International University**
 - **SPAR (MLDUA), AST (WD&C), XL (Integrated System Testing), Others TBD**

FY 1996 TWR PLANS

- **Resolve Long Reach Manipulator Test Bed Procurement**
- **FY 1996 TWR Budget \$800,000.**
 - **Development of tank & waste surface characterization end-effector for residual contamination survey**
 - **Demonstration of flexure control algorithm applied to MLDUA**
 - **Development and demonstration of coordinated control between MLDUA and waste dislodging & conveyance system**
 - **Demonstration of seamless transfer between robotic and teleoperated control.**

GAAT REMOTE SYSTEMS DEVELOPMENT SCHEDULE

- **FY 96 1st Qtr** Evaluations of Available In-Tank Vehicles
MLDUA & WD&C System Design Completed
- 3rd Qtr** Fabrication of MLDUA & WD&C Completed
Controls Software Development Completed
- 4th Qtr** MLDUA, WD&C, Controls Software all
integrated & tested at Cold Test Facility
- **FY 97 1st Qtr** Integrated Cold Tests Completed
- 2nd Qtr** Field Deployment Initiated
- 4th Qtr** GAAT Treatability Study Completed

EM-40/EM-50 PARTNERSHIP GAAT TREATABILITY STUDY

- **EM-50 Tanks Focus Area**
 - Leveraging baseline activities to support MLDUA
 - Design & fabrication of auxiliary systems: TRIC, Decon Spray Ring, Camera System
 - Cold Test Facility Design & Assembly
 - WD&C prototype system development & testing, detailed design
 - Design & fab of gripper end-effector
 - Technology development coordination
- **EM-50 RTDP**
 - Leveraging multi year flexure controls development
 - Developing MLDUA Controls Enhancement
 - Design & fab of characterization end-effector
- **EM-40**
 - All other tasks required for development, testing and operation

TWR BOTTOM LINE

- **As a result of leveraging EM-50 activities ORNL EM-40 has shortened the GAAT-TS schedule by 2 years and saved at least \$4M in equipment costs.**
- **Field Deployment of EM-50 technologies by ORNL EM-40 will prove the value of these technologies for applications across the DOE complex.**

Cross Cutting & Advanced Technology Development

**Dan Horschel, Cross Cutting & Advanced Technology Coordinator,
Sandia National Labs**

Cross-Cutting and Advanced Technologies

Daniel Horschel, Coordinator

Phone: 505 845-9836

E-Mail: dshorsc@isrc.sandia.gov

Scott Slezak, Alternate Coordinator

Phone: 844-2050

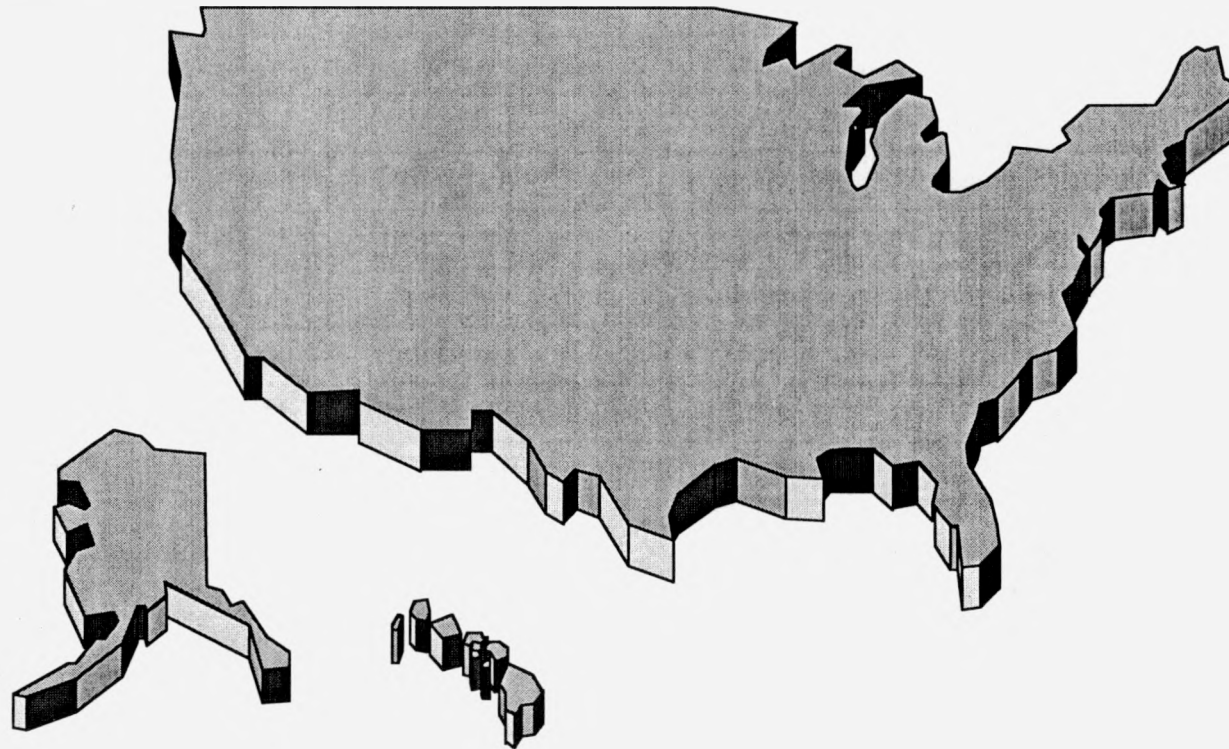
E-Mail: sesleza@isrc.sandia.gov

Home Page: http://www.sandia.gov/cc_at/1cc_at.html



CC&AT Is A Team Effort

- Four National Labs: SNL, ORNL, PNL, LANL
- 14 Universities



CC&AT: Teaming With Universities

University	PI	Technical Area
Georgia Tech	Book	Control of Large Manipulators
Case Western Reserve	Newman	Software Safety
Rice University	Cavallaro/Walker	Failure Mode Analysis
Purdue University	Maciejewski	Kinematic Redundancy
Wisconsin University	Lumelsky	Whole Arm Collision Prevention
New Mexico State University	Hensel	Subsurface Sensor Mapping
Florida University	Tulenko	Hardened Microsensors
Penn. State University	Cannon	Computer Enhanced Operator Interfaces
Washington University	Tarn	Dual Arm Manipulation
University of Minnesota	Papanikolopoulos	Servo Control Using Computer Vision
Carnegie Mellon University	Kanade/Khosla	Reconfigurable and Modular Manipulators
Carnegie Mellon University	Kanade/Khosla	Programming Environment for Robotics
University of Tennessee	Debey	Generalized Telerobotic Control
Colorado School of Mines	Steele	Machine Health Monitoring



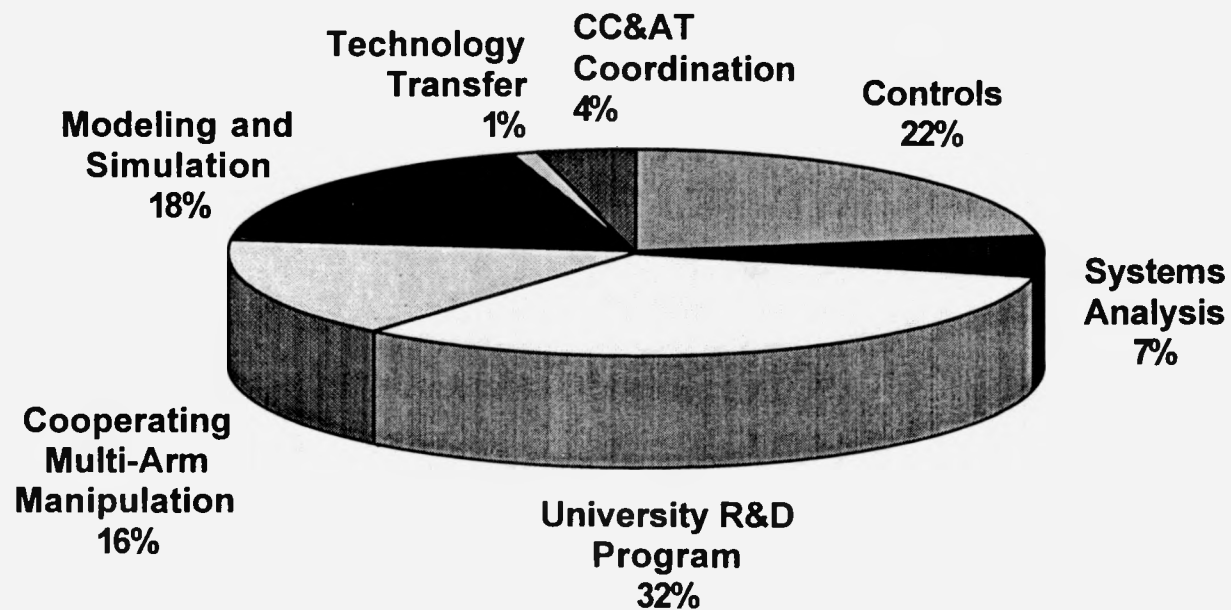
The Purpose of CC&AT

- **Focus Research and Development on Common Needs in the RTDP That Result in**
 - **FASTER**
 - » hazardous waste clean up and
 - » technology development
 - **SAFER**
 - » work conditions for remediation technologists
 - » operation of remediation equipment
 - » automatic enforcement of safe operating procedures
 - **CHEAPER**
 - » life cycle costs (capital, operating, maintenance, and operator training)
 - » technology development costs



FY 1995 Major Thrusts

CC&AT FY 95 Major Thrusts. Total Budget \$5935K

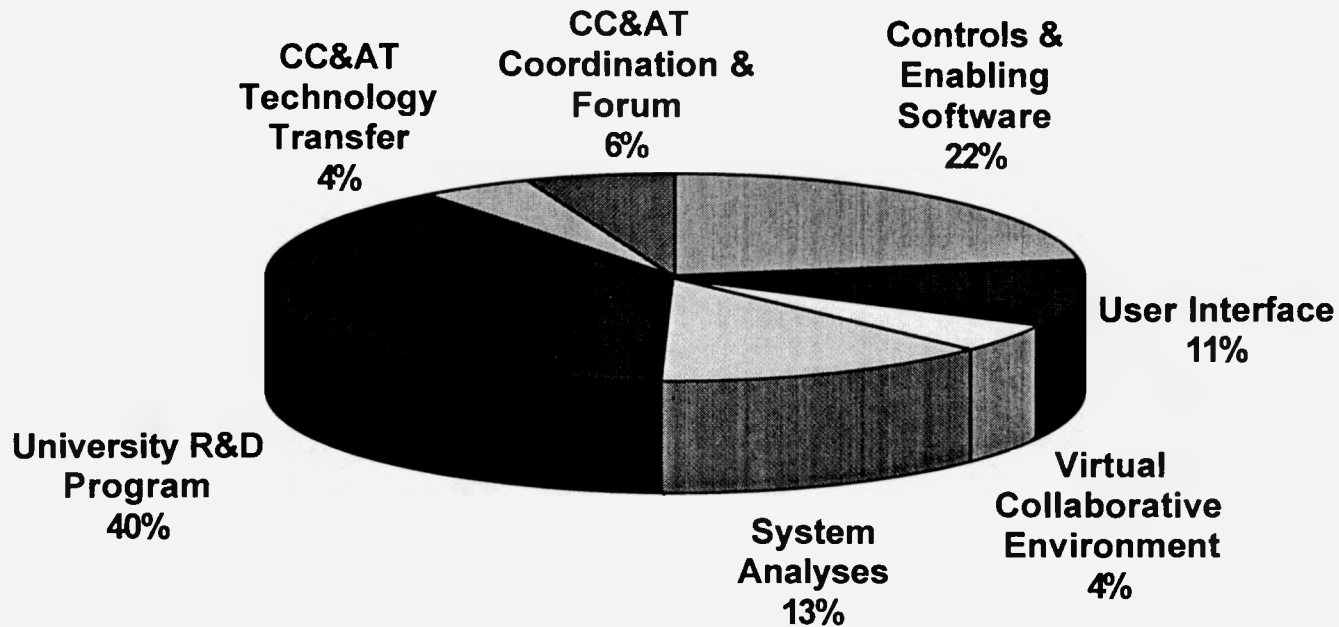


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FY 1996 Major Thrusts

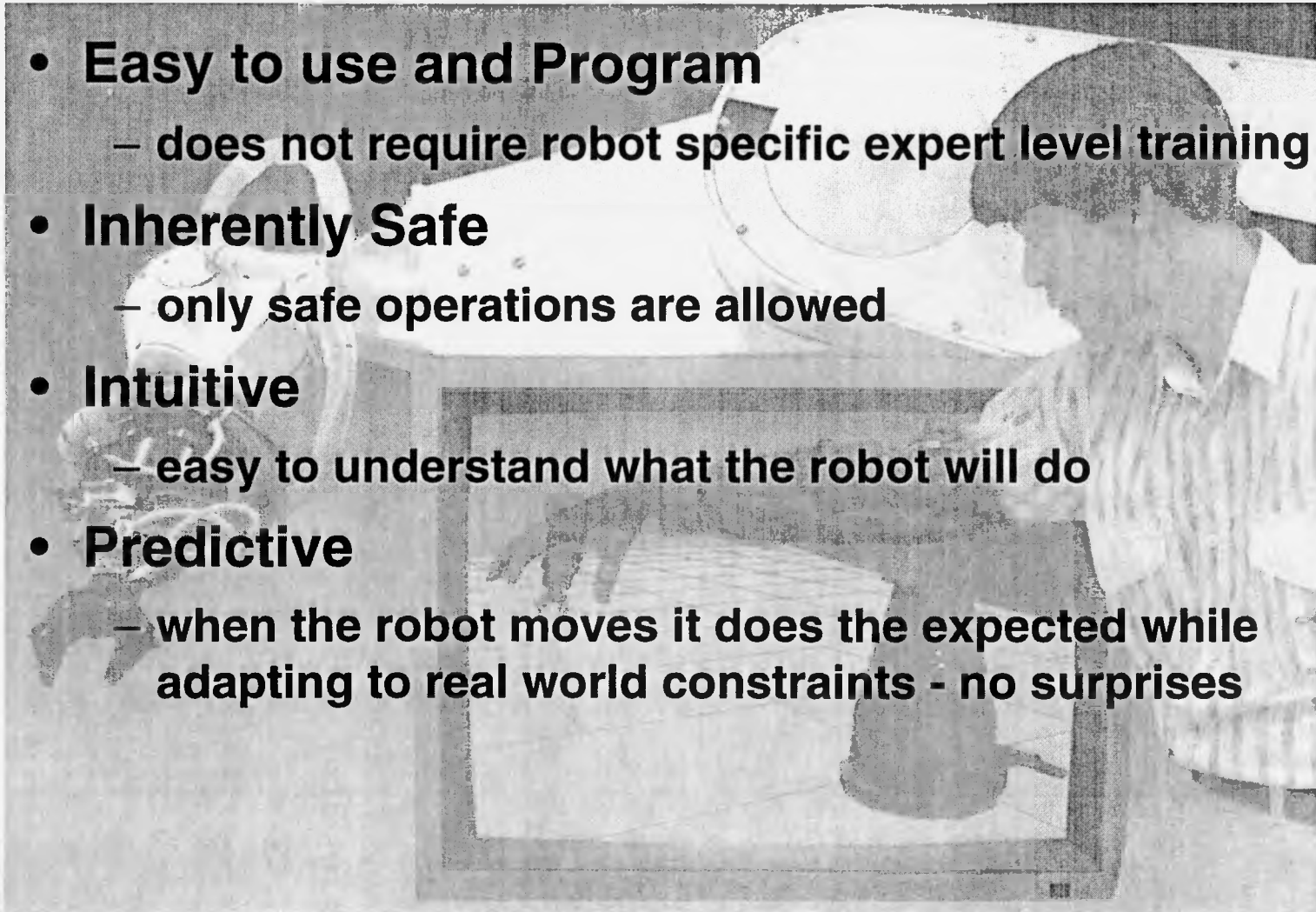
CC&AT FY 96 Major Thrusts. Total Budget \$5120K



RTDP - Cross Cutting And Advanced Technology

What is The Ideal Robot ?

- **Easy to use and Program**
 - does not require robot specific expert level training
- **Inherently Safe**
 - only safe operations are allowed
- **Intuitive**
 - easy to understand what the robot will do
- **Predictive**
 - when the robot moves it does the expected while adapting to real world constraints - no surprises



Achieving the Ideal Robot

- **Advanced Operator interfaces**
- **Automated path planning**
- **Rapid World Model Building**
- **Automated Collision Avoidance**
- **Fault Tolerant Systems**
- **Software Tools for Rapid Integration**
- **Simulation of New Robot Systems**
- **Network based control**
- **Iconic Modular Programming of Controller Functionality**
- **Flexure Control**
- **System Analysis and Cost Benefit Tools**



Graphical Programming and Automated Path Planning

- **Sancho Commercialization**

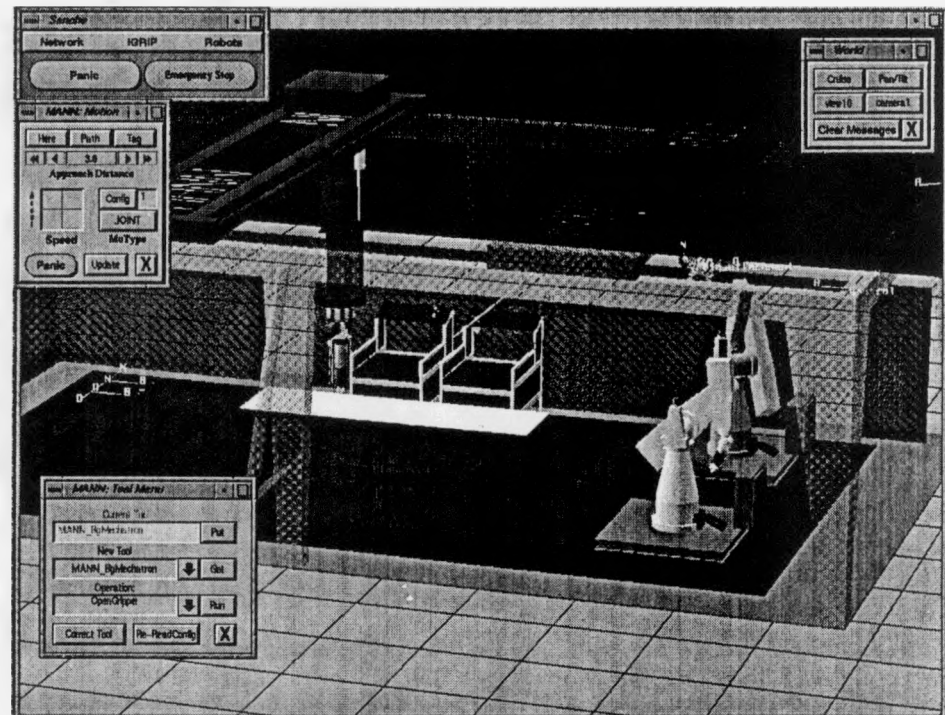
- Task-Based Interface Operational in X GUI
- Leveraging Multi-User VR
- CRADA Being Extended to Include VCE Technologies

- **SANDROS Path Planner**

- Available in Deneb Release 2.4
- Performance Being Enhanced

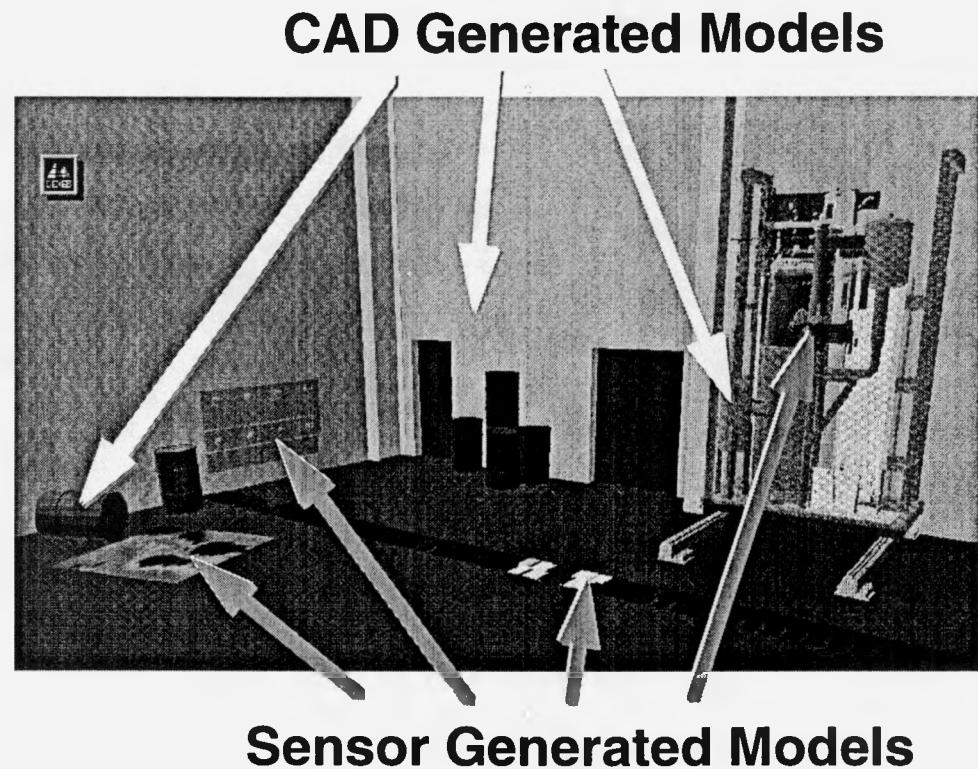
- **GISC Communications**

- Incorporation of Commercial Communications Ongoing



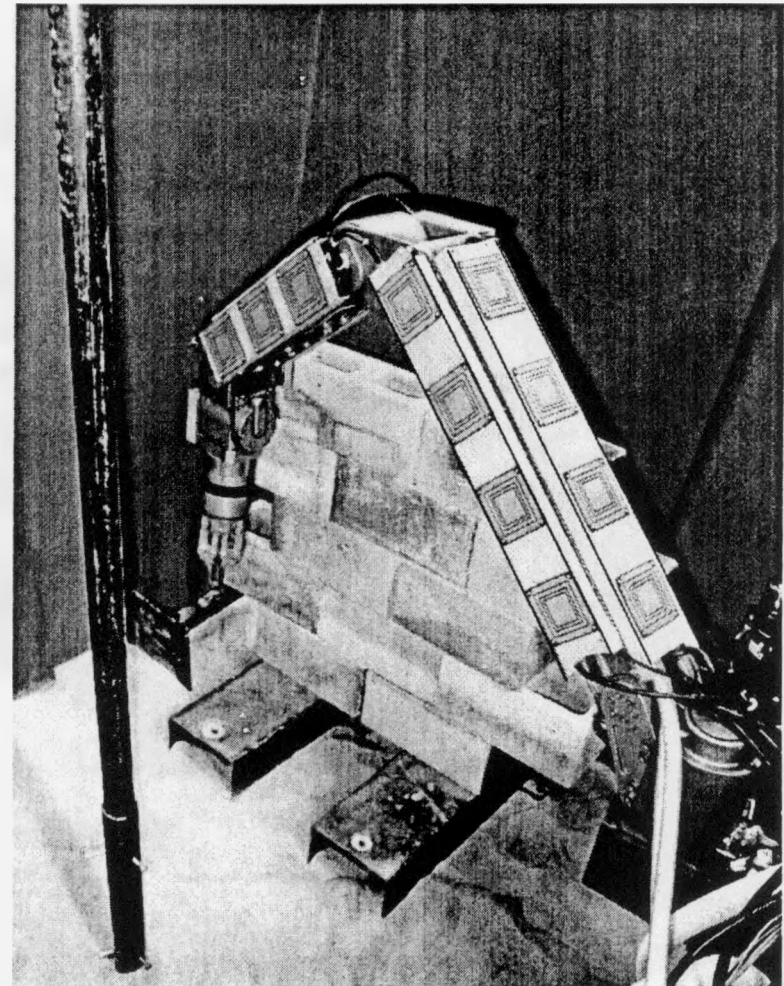
Faster Robot World Model Building

- Needed for Supervisory Control of Robots in Unstructured Environments:
 - D&D, Tanks, Landfills, and MWO
- 3D Imaging and Visualization Workgroup
 - Laboratory, Industry and University Participation
- The Entire Process is Being Worked on by this Group
 - Sensors
 - Data Formats
 - Data Processing
 - Data Display
- Use of Subsurface Mapping and Feature Recognition is Being Addressed



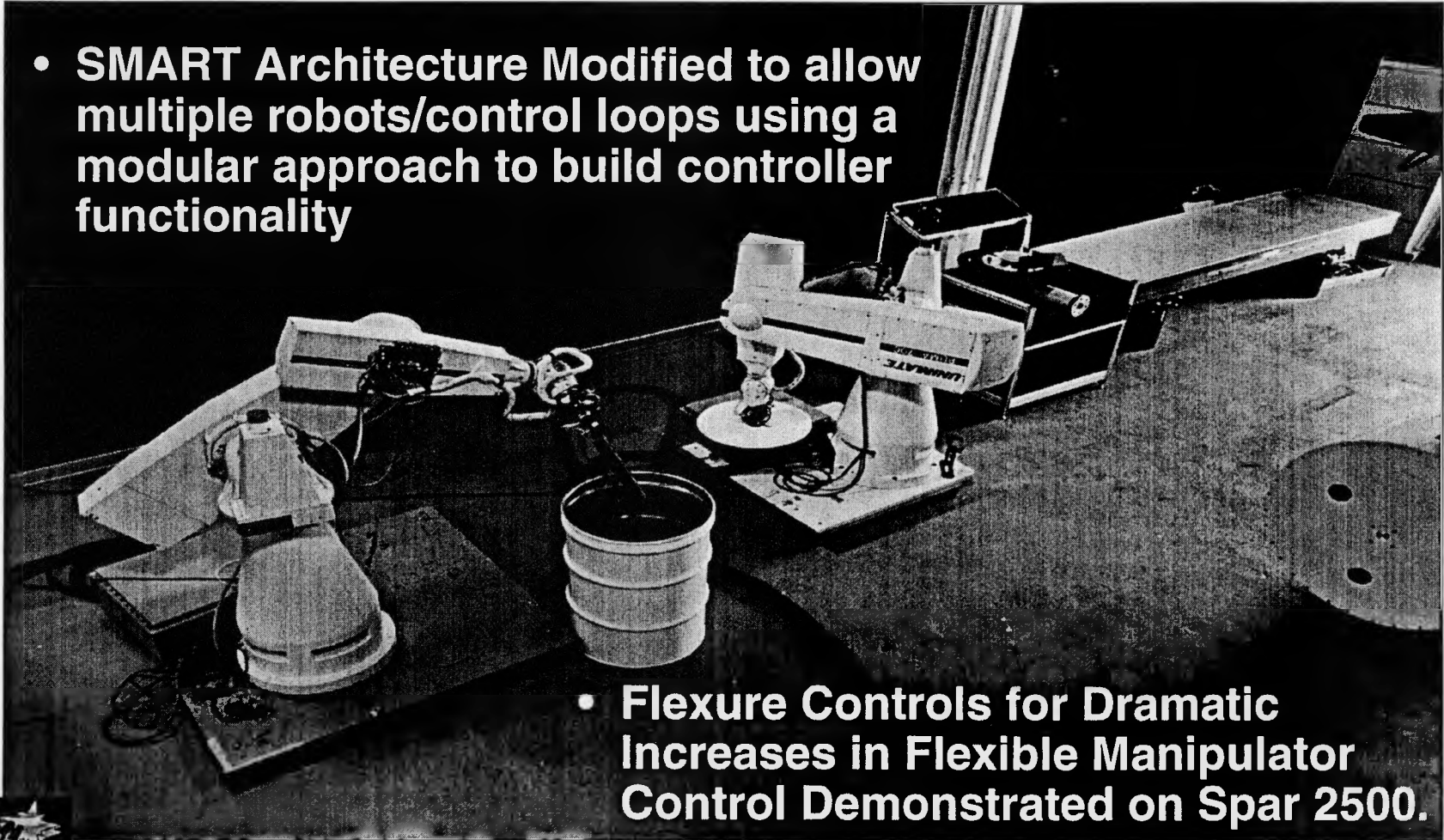
Safer Robot Operation Using Sensor Based Obstacle Avoidance

- **Goal:** To commercialize RTDP-developed Whole-Arm Collision Avoidance Technology for robotics.
- **Purpose:** To create a commercial source for advanced collision-avoidance technology for waste remediation and other DOE projects.
- **Accomplishments:**
 - Demonstrated Whole-Arm Collision Avoidance on Titan manipulator.
 - Worked closely with Merritt Systems to design a new, high-performance sensor to be compatible with MSI SensorBus.
 - Currently beginning prototype fabrication of new sensors.
- **Future:** Commercial product available by the end of FY96.



Improved Robot Controls

- **SMART Architecture Modified to allow multiple robots/control loops using a modular approach to build controller functionality**



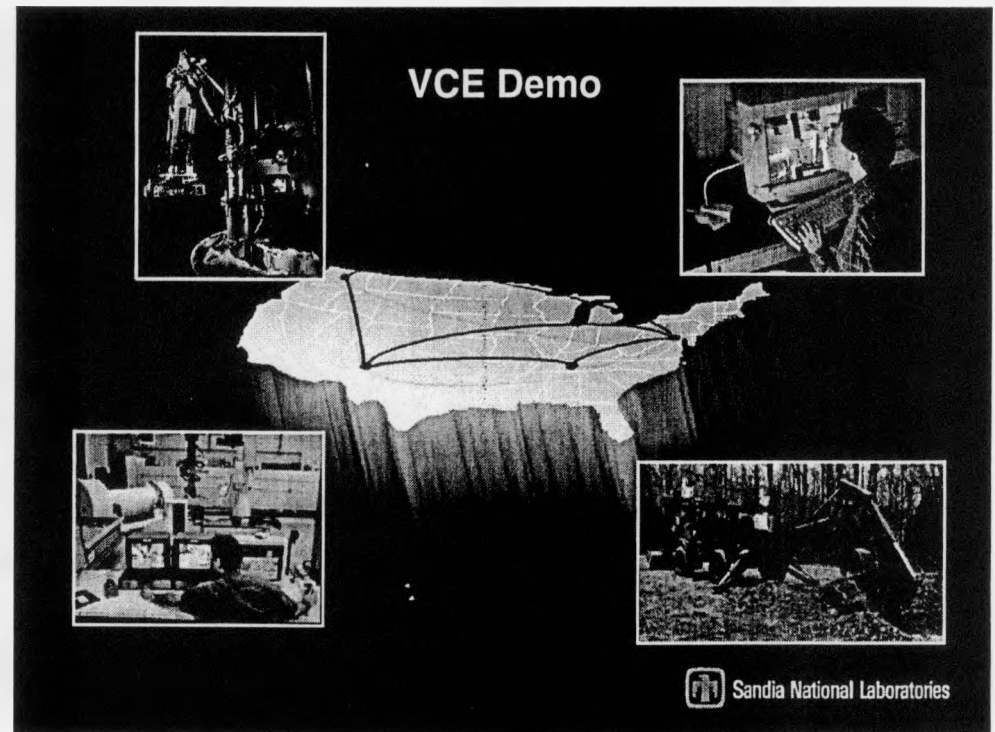
- **Flexure Controls for Dramatic Increases in Flexible Manipulator Control Demonstrated on Spar 2500.**



Bringing the CC&AT Team Closer Together

- **Virtual Collaborative Environment**

- Networks Used to Bring researchers closer together
- 4 Sites Currently Connected Through Dedicated Networks: SNL, ORNL, PNL, NIST
- Investigating Low-cost Options
 - » Existing Networks, Frame Relay Based Networks, low cost Graphical Programming Front Ends
- Will Assess CC&AT University Needs for Participation in FY1996

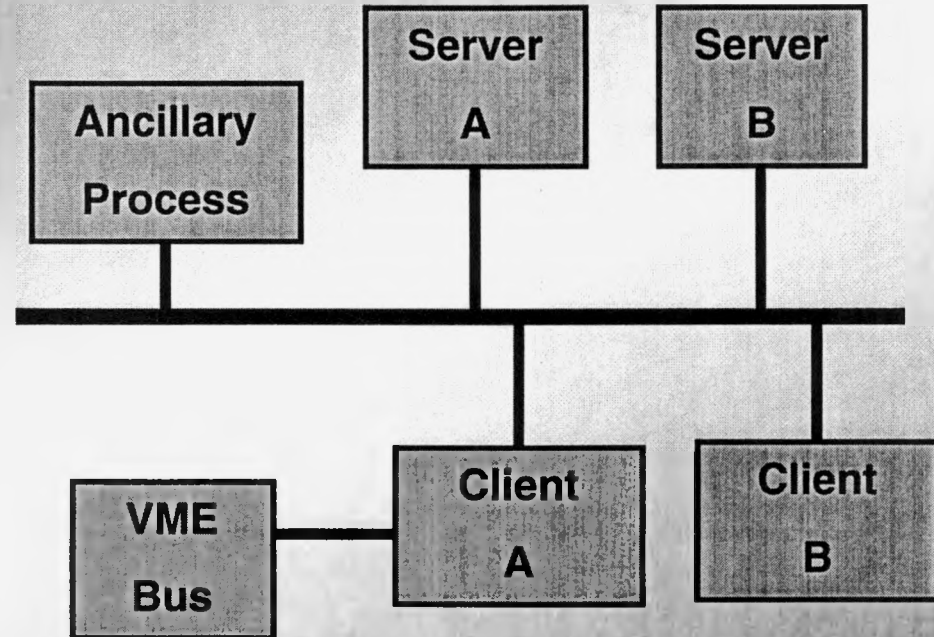


CC&AT: Developing Tools for Faster System Integration

Extension of the GLSC-Kit

Identify and Evaluate a commercially-available communications product for RTDP.

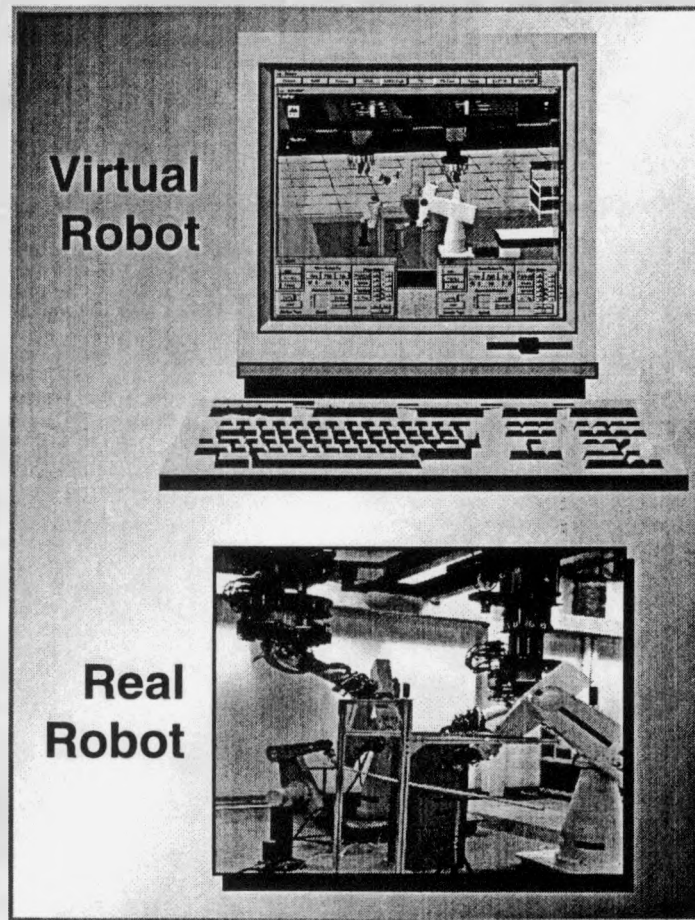
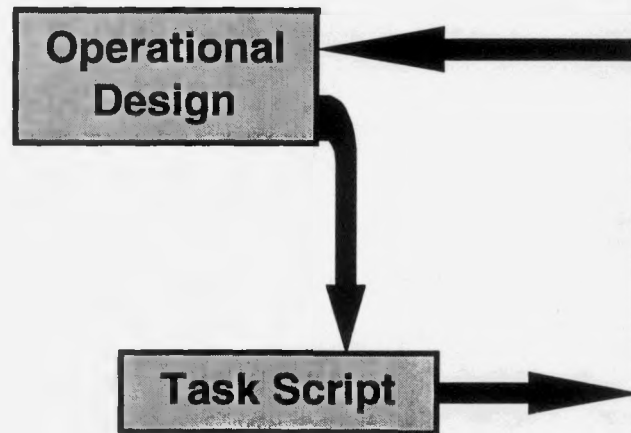
Support distributed, real time supervisory control of robotic subsystems



Client Server Communications



CC&AT: Developing Tools for Faster System Integration



Verify
Virtual
Operation

Implement
Real
Operation

System Composer Contribution



CC&AT System Analysis Activities

- **Collect cost benefit task times**
 - Established general approach to gather primitive robotic task times (December 1994)
 - Completed test plan to gather cost benefit timing information (May 1995)
 - Initial testing underway (July-August 1995)
- **Integrate graphical simulation and cost/benefit analysis**
 - Developed numerical cost model initially focused on underground storage tanks (March 1995)
 - Developed autonomous and teleoperation graphical simulation (July 1995)
 - Integrated cost model and graphical simulation (August 1995)



CC&AT: Achieving the Ideal Robot

- **Easy to use and Program**
 - Graphical Programming
 - Advanced User Interfaces-(e.g. Sancho and Cyberglove)
 - Automated Path Planning
 - Visual Servoing
 - Iconic Programming of Controller Functionality
- **Inherently Safe**
 - Fault Tolerant Analysis and Design
 - Reflexive Control
 - Force Reflection
 - Kinematic Redundancy
 - Rad-hardened Design/Components
 - Whole Arm Obstacle Avoidance
 - Faster World Modeling and Visualization
 - Machine Health Monitoring



CC&AT: Achieving the Ideal Robot

- **Intuitive**

- Simulation of tasks before executed by hardware
- Generalized Master-Slave Design
- Fast World Model Building
- Sub-Surface Imaging
- Software “Experts” for Guiding the Operator
- Generalized Approach to Controlling Multiple Robots
- Generalized Approach to System Design Using Enabling System Software
- System Analysis During Conceptual Designs

- **Predictive**

- when the robot moves it does the expected while adapting to real world constraints - no surprises



CC&AT: Keeping in Touch

- **The Sixth DOE Industry/University/Lab Forum on Robotics for Environmental Management**
 - See many of these technologies in action during the tours on Thursday afternoon
- **See the CC&AT Home Page for information, activities, accomplishments, etc.**
 - http://www.sandia.gov/cc_at/1cc_at.html



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