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ABSTRACT

The Robotics/Automated Systems Technician (RAST) project developed a robotics technician model curriculum for the use of state directors of vocational education and two-year college vocational/technical educators. A baseline management plan was developed to guide the project. To provide awareness, project staff developed a dissemination plan (articles in major publications), prepared and mailed a project abstract, presented three papers at conferences, and delivered a product report. A panel of experts was assembled as a project advisory committee. The project produced a state-of-the-art report, robotics/automated systems task analysis and job competency report, and teaching/learning modules and new module outlines for a RAST curriculum. Recommendations were the development of modular instructional materials to support the six specialty courses in the RAST curriculum and the undertaking of similar curriculum projects to provide national models for technician education/training on other emerging, advanced technology areas. (Appendixes, amounting to approximately four-fifths of the report, include samples of visibility activities, information activities (project fact sheet, project brochure, and conference papers), advisory committee meeting minutes, robotics/automated systems task analysis listing, and core curriculum explanation.) (YLB)

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Robotics/Automated Systems TECHNICIAN TRAINING

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FINAL REPORT
Volume 1

Project No. 051MH30009
Contract No. 300-83-0122

Daniel M. Hull James E. Lovett
Center for Occupational Research and Development
Waco, Texas

TASK ANALYSIS AND JOB DESCRIPTIONS FOR ROBOTICS/AUTOMATED SYSTEMS TECHNICIANS

April 1985

UNITED STATES DEPARTMENT OF EDUCATION

Office of Vocational and Adult Education
Division of National Vocational Programs

EXECUTIVE ABSTRACT

Modern manufacturing and processing industries require broadly trained, interdisciplinary technicians to install, maintain, repair and modify production equipment. These technicians must work in a rapidly-changing field and will require frequent updating on new equipment, materials, instrumentation and techniques. The postsecondary curriculum for Robotics/Automated Systems Technicians (RAST) was designed to provide a broad technical base and allow the graduate technician maximum flexibility and lateral mobility in the work environment.

Robotics and Automated Systems Technology embraces three major areas of work:

- Systems Development
- Flexible Manufacturing Systems
- Hard Automation Systems

This RAST curriculum project included determination of the location, quality and content of existing programs, task analysis, curriculum design, specialty course and module outline development and program information dissemination. There are currently 56 schools offering robotics/automated systems technician training; however, most of the programs are narrow and substantially electronic in design. The curriculum model designed on this project includes a "core" of basic and technical courses which are common to other electromechanical technician specialties, plus six specialty courses in Robotics/Automated Systems Technology. Complete course and module designs are provided for the specialty courses.

Efforts are being made to obtain private funding for the development of the module outlines into classroom courseware.

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The work reported herein was performed pursuant to a contract with the Office of Vocational and Adult Education, United States Department of Education. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Department of Education position or policy.

UNITED STATES DEPARTMENT OF EDUCATION

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PREFACE

The incorporation of robots into manufacturing systems is occurring at an ever-increasing rate. Technicians who can install, modify, and maintain these new "high-tech" devices are needed by industry. Many postsecondary vocational schools have responded to the requirement to train robotics technicians by either offering one or two courses as an option to an electronics or manufacturing program, or hurriedly developing a technician program that seemed to meet local needs. These two approaches have led to an inconsistent hodge podge of programs and courses in various schools and institutions.

The United States Department of Education, Office of Vocational and Adult Education, issued a contract to the Center for Occupational Research and Development to develop a model curriculum that schools could use as a guide when establishing a new program or modifying an existing one. The curriculum would be based upon a core of courses that are common to training technicians in advancing-technology fields. This core includes courses such as fundamentals of electricity and electronics, electromechanical devices, mechanical devices and systems, instrumentation and control and practical physics.

This project developed six specialty courses that build upon the broad-based interdisciplinary core. These six are Fundamentals of Robotics and Automated Systems, Controllers for Robots and Automated Syscems, Automated Systems and Support Components, Robotics/Automated Systems Interfaces, Robotics/Automated Systems at Work, and Automated Work Cell Integration. Each course was developed to the extent of having four to seven module outlines. Each module is specific to one portion of the course and can be taught independently, but in sequence with the other modules.

The Final Report for this very timely project is written in two volumes. Volume 1 describes the processes followed in the development of the model Robotics/Automated Systems Technician curriculum. Volume 2 is a Curriculum Planning Guide--a detailed step-by-step procedure that institutions and schools can follow when establishing or modifying a Robotics/Automated Systems Technician training program.

CONTENTS, Volume 1

INTRODUCTION

BACKGROUND

In recent years, U.S. manufacturers have faced a great challenge to remain competitive within their own industry--that challenge is whether or not to automate. The challenge arises from the need to reduce the cost of manufacturing a product. Labor costs constitute a major portion of the cost to produce most goods manufactured in the U.S. As labor costs escalate, especially in labor-intensive industries, manufacturers evaluate alternate methods of production in order to reduce costs. These methods most often include incorporating automation to reduce production labor costs.

However, the introduction of automation creates new problems for employers, such as, "Which employee will be responsible for installing, maintaining and modifying the new "high-tech" automated equipment?" In many companies engineers are reassigned as technicians to support installation, setup, and operation of automated equipment. This practice robs the company of creative talents critically needed in the development of new products. What these companies really need is technicians who have been trained in broad-based, interdisciplinary skills and have specialized in robotics and automated systems. With an adequate number of technicians available, engineers could be returned to their normal creative jobs.

TECHNICIAN SKILLS

The required technicians will be able to work on a wide variety of robots and automated systems--including electric, pneumatic and hydraulic. The technician should be able to operate on control systems, sensors, and drive systems, in addition to the robot structure; this is to say that technicians should be interdisciplinary. The skills required include:

- Connecting, calibrating/adjusting, reading and interpreting electrical/electronic measuring devices.
- Reading, understanding and interpreting operator's manuals, blueprints and schematics.

- Installing, calibrating, modifying sophisticated, automated devices.
- Troubleshooting, repairing, and returning to service this same sophisticated equipment.

While the above is a lengthy list of skills requirements for technicians and the systems to which skills and knowledge must be applied, it is not complete. Even if the list were complete for today, tomorrow will bring the introduction of new technologies and systems. Technicians being trained today must gain an understanding of and an appreciation for basic "operating" principles of many different systems--thermal, mechanical, electrical, hydraulic, and structural. This is the broad base, the foundation, upon which they will advance their skills and knowledge as technologies advance.

CURRICULUM DESIGN

When school administrators consider adding a new curriculum for Robotics/Automated Systems Technician (RAST) training, outside help is frequently sought. The field of robotics and automation is so new and the technology so advanced that institutions seldom have faculty personnel who are sufficiently knowledgeable about robotics and automation that they can design their own curriculum. A Robotics/Automated Systems Technician Training Curriculum Guide*, produced as part of a national project to design a model Robotics/Automated Systems Technician curriculum, is included as Volume 2 to this report. This is not one of the specific products of this project; however, it is and will be very useful when used by school faculty and administrators. It is a companion to an "Advanced Technology Core Curriculum Guide"* prepared by the Center for Occupational Research and Development. Together, the two guides direct administrators and faculty through the activities involved in establishing a new Robotics/Automated Systems Technician Curriculum. The steps described include establishing a local advisory committee, preparing a task analysis, validating courses and course requirements, staffing, and purchasing equipment.

Close coordination with local manufacturers is required during the curriculum design process. It is these manufacturers who will "utilize" the

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*Available from the Center for Occupational Research and Development, 601 Lake Air Drive, Waco, Texas 76710.

product of educational institutions, or who will provide in-house training as necessary. They must provide input in the design process in the form of defining what tasks are required of (entry-level) technicians. If such a list is not available, the employers, hopefully, would be willing to help in its development.

When the required tasks have been identified, school officials or training personnel can group them according to similarity of skills to be learned or equipment to be worked with in the educational process. The culmination of this effort will form the basis of identifying specific courses to be taught to meet the needs of employers.

PROJECT ACTIVITIES AND RESULTS

The United States Department of Education, Office of Vocational and Adult Education (OVAE), in 1982 recognized that many schools across the United States were establishing Robotics Technician curricula and offering training in robotics. The OVAE also realized that, due to the quickness with which these courses and curricula were assembled, there was little opportunity for in-depth planning in most cases and that there would be a wide variance in curricula and course content among the schools involved.

These facts brought to the forefront the need for a robotics technician curriculum model that would be available to any school upon request. This model could be studied, discussed, and modified by school administrators to fit local needs. It would include all the basic elements required for training broad-based, interdisciplinary Robotics/Automated Systems Technicians.

On August 21, 1983, OVAE, awarded an eighteen-month contract to the Center for Occupational Research and Development (CORD). The purpose of the contract was to develop a model curriculum as described above. The different aspects and deliverables required by the contract are described on the following pages. The work that CORD performed was divided into eight specific tasks with deliverables. Each task is identified below, with a description of the work accomplished and the results obtained.

TASK A--BASELINE MANAGEMENT PLAN

Accompanying CORD's original proposal was a plan--the Baseline Management Plan--that described the functions of each of the participating personnel/operating groups and a schedule of events to be completed. After contract initiation, only two items required changing. Specific dates were identified on the schedule rather than having dates identified as time lapsed from the beginning of the contract, and James E. Lovett was identified as a Research Associate for the project--Mr. Lovett joined CORD between submission of the proposal and initiation of the contract. The Baseline Management Plan was followed throughout the project. The duration of the project was extended two months to allow maximum attendance at the third meeting of the Panel of Experts.

TASK B--PROJECT AWARENESS

The existence of the curriculum model and course and module outlines developed by this project were made known to school administrators and faculty. To provide awareness, CORD expended efforts and developed the products described below.

- Dissemination Plan - The dissemination plan, discussed in Task B, Item 1, of the RFP and the proposal addressed the need to inform the postsecondary administrators and faculty of the existence of this program and its products. The effort expended in disseminating information about this project includes having announcements published in major trade magazines and journals and follow-up letters to individual requests.

  - Articles in Major Publications - In September 1983, four national professional organizations were formally requested to publish information about this project. Letters were sent to Robotics International of the Society of Manufacturing Engineers, the American Vocational Association, the National Society of Professional Engineers, and the American Society of Engineering Education, each letter requesting publication of an enclosed news release. Copies of the letters to publishers and the news releases are included in Appendix A.

    Robotics Today, a publication of Robotics International of the Society of Manufacturing Engineers (RI/SME) published an announcement of the project in their February 1984 issue.

    In June 1984, letters were again sent to publishers of four periodicals requesting announcement of the availability of the State-of-the-Art Report (one of the products of this project). Letters were sent to the American Vocational Association, the American Association of Community and Junior Colleges, the Society of Manufacturing Engineers and Robotics Age magazine.

    Robotics Age printed an announcement in their September 1984 issue.

The magazine news articles described previously resulted in requests for further information concerning the purpose and products of this project. A list of the persons who requested information, and a copy of the letter and information sent are included in Appendix A.

- Project Abstract - A one-page fact sheet describing the project was prepared and mailed to approximately 150 persons who requested it. There were also a considerable number--undocumented--of telephone calls discussing the major aspects of the project. The original fact sheet was updated in May 1984 with the printing of a one-page/two-sided brochure. Both are included in Appendix B. Approximately 800 copies of the brochure were distributed at the Robots 9 Conference in Detroit, Michigan, June 4-7, 1985, and at the Robotics International Education and Training Conference in Romulus, Michigan, August 22-23, 1984. An additional 100 copies have been mailed to other requesters.
- Papers Published and Presented - Three papers have been presented at major conferences concerned with robotics and training. A fourth will be presented later this year. Each paper was or will be included in the proceedings of the specific conference. All papers are included in Appendix B.
  - Robots 8 Conference, Detroit, Michigan, June 7, 1984. Mr. James E. Lovett and Mr. Daniel M. Hull co-authored a paper entitled "A National Model for Training Robotics/Automated Systems Technicians." This paper received the "Outstanding Paper of the Year Award." The session at which this paper was presented was attended by approximately 400 educators and industry trainers. The abstract for the paper follows.

    Education programs for robotics technicians in the United States today are needed to keep pace with rapidly expanding use of robots. Carefully trained technicians are needed to troubleshoot, repair, adapt, interface, and assemble/disassemble the different types of robots. The United States Department of Education, Office of Vocational and Adult Education, has issued a contract to develop a national model curriculum for robotics technicians. The Center for Occupational Research and Development (CORD), as contractor, has already established prototype, broad-based technical core curricula for high-technology programs. CORD, under guidance of a panel of experts, is adapting the technical core prototype and designing special robot courses to meet requirements for robotics technicians. In the process, CORD will perform task analyses, develop required competencies, identify specific courses required and prepare needed course outlines. Results of the 18-month project will be available to institutions that are establishing new robotics programs or modifying existing robotics programs. Robot competencies, task analyses, and education curriculum--technical core and specialty courses--that CORD is developing for the national model curriculum are discussed.

•• RI/SME Education and Training Conference, Romulus, Michigan, August 22-23, 1984. Mr. James E. Lovett presented "Robotics/Automated Systems Technician Training in the U.S.A.--A State-of-the-Art Report." This conference was attended by approximately 200 school administrators and instructors. The abstract follows.

The Center for Occupational Research and Development and Robotics International of the Society of Manufacturing Engineers conducted a survey to determine the state of the art of Robotics/Automated Systems Technician Training. The results of this survey indicate that 56 postsecondary institutions currently provide robotics technician training. Additionally, there are 114 schools that offer robotics courses as electives. There are currently 159 instructors (76 with Masters degrees and seven with PhD degrees) teaching robotics, and 5,472 students studying to become robotics technicians in two-year associate degree and certificate programs.

Very few of the programs evaluated provided broad-based interdisciplinary training for the students. There is a great need to upgrade the quality of Robotics/Automated Systems Technician training.

•• InteRobot 84, Long Beach, California, October 10-12, 1984. Mr. James E. Lovett presented the paper "Education for Robotics/Automated Systems Technicians." This session of the conference was attended by approximately thirty secondary and postsecondary educators. The abstract follows.

Education programs for robotics technicians in the United States today are needed to keep pace with the rapidly expanding use of new and different robots in the workplace. Carefully trained technicians are needed to troubleshoot, repair, adapt, interface, and assemble/disassemble the many different types of robots.

The United States Department of Education, Office of Vocational and Adult Education, recognized this need and issued a contract to develop a national model curriculum for robotics technicians. The Center for Occupational Research and Development (CORD), as the contractor, has already established prototype, broad-based technical core curricula for high-technology programs. CORD, under the guidance of a Panel of Experts, is adapting the technical core prototype and designing special robot courses to meet the requirements for robotics technicians. In the process CORD will perform task analyses, develop required competencies, identify specific courses required and prepare the needed course outlines. Results of the eighteen-month project will be made available to institutions that are establishing new robotics programs or modifying existing robotics programs.

This presentation will describe the robotics competencies, task analyses, and education curriculum--technical core and specialty courses--that CORD is developing for the national model curriculum.

•• RI/SME Education and Training Conference, Plymouth, MI, scheduled for August 12-14, 1985. Mr. James Lovett and Mr. Daniel M. Hull co-authored a paper entitled "A National Model Robotics/Automated Systems Technician Curriculum." The abstract follows:

The Center for Occupational Research and Development has recently completed an extensive project on research and curriculum development for Robotics/Automated Systems Technicians (RAST). This work, sponsored by the Office of Vocational and Adult Education, U.S. Department of Education, identified the extent and quality of current RAST training and developed a national model curriculum with courses and module outlines.

The National Advisory Committee for Robotics/Automated Systems Technician Training, formed to guide the progress of this report, established baseline criteria for the RAST curriculum. They determined that the technician should be trained in broad-based, interdisciplinary programs. Students should be trained to install, maintain, repair and/or modify systems and subsystems that are part of automated equipment. A study conducted during this contract work determined that there are currently 56 intitutions training 5472 students to be robotics/automated systems technicians; however, nearly all of the curricula currently in place are very narrow and highly specialized--that is, they are not broad based and interdisciplinary.

The model curriculum is available to institutions to use as a guide in establishing new or revising existing programs. It includes job competencies, course outlines, and objectives and laboratories for courses in applied physics, electromechanical devices, electrical and electronic devices, hydraulics, pneumatics, controllers, computers, sensors, vision, robotic interfacing and work-cell integration.

- The Project Director and the Research Associate, during CORD's normal business activities, and at meetings at several schools, had opportunities to discuss/describe this project with many school officials across the U.S. The schools with which these meetings took place are listed below.
  - Francis Tuttle Vo-Tech Center, Oklahoma City, Oklahoma. Mr. Bruce Gray, Dr. Gene Callahan, Mr. Jim Wilson, Ms. Millie Clarke.
  - Oklahoma City Community College, Oklahoma City, Oklahoma. Dr. Donald Newport, Dr. Bob Todd, Dr. Curt Lezanic.
  - Lorain County Community College, Elyria, Ohio. Dr. Walter H. Edling.
  - Cuyahoga Community College, Cleveland, Ohio. Dr. Nolen Ellison, Dr. Curtis Jefferson, Dr. Dave Mitchell, Mr. Russell Cooper, Mr. Michael Taggart.
  - Des Moines Area Community College, Des Moines, Iowa. Mr. Norm Luikens, Mr. Tom Dunsmore.
- Product Report - This is a short report--five pages long--that describes each of the major products of this project--The State-of-the-Art Report, Task Analysis Report, and Model Curriculum Report (Robotics/Automated Systems Curriculum Guide) and the Final Report. The product report is now available to persons and schools who request information concerning the development of a new Robotics/Automated Systems Technician Curriculum.

TASK C--USE OF PROJECT ADVISORY COMMITTEE (PANEL OF EXPERTS)

Rather than CORD personnel developing all the material required for this contract from a single, or at best very narrow, point of view, CORD assembled a Panel of Experts (POE) as an advisory committee. Names of candidates for membership, and their letters indicating willingness to participate were included in the original proposal. Twelve persons were selected from the original list of candidates; included in this selection were five persons from industries that either manufacture or use robotic equipment, and seven persons involved in education in robotics.

An extensive effort was made to obtain the cooperation of organized labor. Several contacts with the United Auto Workers offices in Detroit, Michigan, were made--all without results. Finally, CORD was referred to the Washington, DC, office of the International Brotherhood of Electrical Workers. Mr. Ken Edwards, Education Department of IBEW, agreed to serve as a labor representative on the POE.

Additionally, two other educators expressed a desire to CORD to be included on the POE. One was included in the original list of candidates and one was not. Since the contract required twelve members, and there were several other persons who indicated an initial willingness to serve, these two persons were included as Advisory Members.

The POE met formally three times to review and comment upon materials being developed and the project's progress and to offer suggestions for improvement; the review process ensured that materials developed would be part of a broad-based interdisciplinary curriculum. The POE meetings were scheduled at key times--times when "outsiders'" inputs were especially valuable to the development of a meaningful curriculum guide. Meetings were scheduled at times and in places that facilitated a maximum participation by the individual members. Appendix C includes a list of the POE members and agenda and minutes for all three meetings.

First POE Meeting

The first meeting was held October 19, 1983, at the Society of Manufacturing Engineers (SME) headquarters in Dearborn, Michigan. The purpose of this project was described, followed by an explanation of the core curriculum concept of courses as applied to (robotics) technician training. The morning session concluded with the following:

1. Development of a RAST job description, which follows:

Robotics/Automated Systems Technicians are technical specialists with broad-based electromechanical skills who are familiar with electronic, mechanical, hydraulic and pneumatic devices. They are usually specialists in robotics or processing equipment and can set up automatic machines that work together as part of a total automated system. In their area of specialization, they can install, set up, troubleshoot, integrate, program, modify, test, operate and repair systems and components. They are field-service, installation or service technicians. They work either under the supervision of an engineer, as a member of a team or as a supervisor of other technicians.

2. A recommendation that the project name and scope be changed from "Robotics" to "Robotics/Automated Systems."

3. The curriculum to be developed should be broad based and interdisciplinary.

Discussions in the afternoon sessions centered around a list of tasks that a technician would be required to perform. The list presented for discussion was edited from a compilation of several lists developed independently and provided for use by the project staff. The organizations providing lists included:

- Piedmont Technical College, Greenville, South Carolina
- Texas State Technical Institute, Waco, Texas
- The National Center for Research in Vocational Education, Columbus, Ohio
- Oakland Community College, Auburn Heights, Michigan
- Lorain County Community College, Elyria, Ohio

At the suggestion of the POE, the list of tasks was revised by grouping the tasks according to the major system with which they are associated and mailed to each member. The tasks were separated into the following areas: Electrical/Electronics, Pneumatics, Hydraulics, Mechanical, Computer, Electromechanical, General, Manufacturing Processes, Automated Systems, and Design. Each person then noted the relative importance of each competency and returned the rankings to CORD. CORD staff tallied the rankings and analyzed the results. Based upon the results, the task listing was revised and later submitted to the POE as described below.

Second POE Meeting

On March 16, 1984, the second POE meeting was held at the Dallas/Fort Worth, Texas, airport. After a report of project progress, the rankings of the task listing were discussed. The POE said the competencies that had been deleted, while not critical, were important and should be retained. These competencies were added to the list and titled enabling competencies. The last part of the meeting was spent reviewing a course/competency matrix. This matrix identified which course satisfied the requirements of each competency.

Third POE Meeting

The Ford Motor Company hosted the third POE meeting on November 6, 1984, at their Robotics and Automated Manufacturing Consulting Center in Dearborn, Michigan. The majority of this meeting was spent reviewing descriptions of specialty courses and their supporting module outlines.

TASK D--STATE-OF-THE-ART REPORT

An important aspect of embarking upon the design of a model curriculum for training Robotics/Automatic Systems Technicians was to determine what RAST training existed in the United States. Robotics International of the Society of Manufacturing Engineers worked with CORD in surveying public and private educational institutions. (The survey was funded completely by the RI/SME.) RI/SME conducted the survey as part of the effort to update their "Directory of Schools Offering Robotics Training." Information obtained from the survey was provided to CORD for their analysis.

The results of this study* indicated that 56 postsecondary institutions provide robotics technician training. An additional 114 schools offer robotics courses as electives. Currently there are 159 instructors (76 with Masters degrees and seven with PhD degrees) teaching 5472 students who are studying to become robotics technicians. Thirty-three texts were identified as being used in the robotics training; however, only one of these was known to be competency based.

TASK E--ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS AND JOB COMPETENCY REPORT

The design of a curriculum for training technicians requires two items of information--the technician job description and the tasks the technician will be expected to perform upon initial employment as a RAST.

A preliminary job description was reviewed and revised by the POE and is provided in the discussion of the October 19, 1983, POE meeting.

A list of robotics technician tasks was completed from the six task listings previously referenced. The list was presented to the POE, who suggested several improvements relative to wording and organization as follows:

*Data contained in the State-of-the-Art Report, available from the Center for Occupational Research and Development, 601 Lake Air Drive, Waco, Texas 76710. (1/800-231-3015)

- Terminology should be consistent throughout the list.
- Competencies related to a type of system should be grouped together under an identifying heading such as "Hydraulics."
- Competencies should be identified as terminal or enabling. A terminal competency is one that an employer expects a technician to be able to perform. An enabling competency is a skill or piece of knowledge that facilitates performance of terminal competencies.

The revised task listing for Robotics/Automated Systems Technicians is included in Appendix D of this report.

TASKS F AND G--TEACHING/LEARNING MODULES AND NEW MODULE OUTLINES

One of the objectives of this project was to design a Robotics/Automated Systems Technician curriculum that uses a "core" of courses common to training technicians in several fields of advancing technology. The rationale for having a curriculum designed around a core is described briefly in Appendix E. The core of courses--all designed to be one-quarter long--included for consideration for the model RAST curriculum were:

- Algebra
- Trigonometry
- Analytic Geometry/Calculus
- Technical Physics
- Technical Communications
- Industrial Relations
- Fundamentals of Electricity and Electronics
- Computer Basics
- Economics in Technology
- Electronic Devices
- Digital Electronics
- Analog Circuits and Active Devices
- Industrial Electricity
- Graphics
- Properties of Materials
- Mechanical Devices
- Electromechanical Devices
- Heating and Cooling
- Fluid Power
- Instrumentation and Control
- Computer Applications
- Industrial Electrical Power and Equipment

A description of each of these courses is included in Volume 2. The implementation of a core curriculum is explained fully in the Advanced-Technology Core Curriculum Guide.*

Determination of the requirement for each course was accomplished by listing the competencies (approved by the POE) down the left side of a page and the common courses across the top of a page as shown in Appendix D. The competencies were identified with the course in which they would be taught. An analysis was made to ensure that each course satisfied sufficient competencies to warrant its inclusion in the final model. The initial matrix

*Available from the Center for Occupational Research and Development, 601 Lake Air Drive, Waco, Texas 76710. (1/800-231-3015) indicated that the Heating and Cooling course would contain only four required competencies. Examination of the competencies satisfied by Technical Physics showed that the competencies originally identified with Heating and Cooling would be satisfied by the Heat Transfer portion of the Technical Physics courses. The Heating and Cooling course was deleted from the core.

Similar analyses indicated that, in the electrical and electronic areas more emphasis should be placed on digital and analog devices and systems than could be provided in the course on Electronic Devices. Therefore, the Electronic Devices course was deleted; competencies that had been identified with this course were realigned with the three remaining courses: Fundamentals of Electricity and Electronics, Digital Electronics, and Analog Circuits and Active Devices.

When the initial process of identifying the relationships of competencies with their respective courses was complete, sixty competencies were not associated with an existing course. These competencies were the basis for designing the RAST specialty courses. Six specialty courses, with their corresponding competencies, were proposed at the second POE meeting; these courses were: Fundamentals of Robotics and Automated Systems, Automated Control Systems I and II, Robotics/Automated Systems Applications, Robotics/Automated Systems Specifications, Robotics/Automated Systems Projects. The POE recommended changing the courses to Fundamentals of Robotics and Automated Systems, Controllers for Robots and Automated Systems, Automated Systems and Support Components, Robotics/Automated Systems Interfaces, Robotics/Automated Systems at Work, and Automated Work Cell Integrations, and realigning the competencies accordingly. Although not listed as a set of competencies, Fundamentals of Robotics and Automated Systems addresses the human factors aspects of the human/automation interface. Despite the appearance that the application of robots and automated systems is oriented toward manufacturing, the specialty courses address the requirements for training technicians to service robots in any setting--offices, medical and so forth.

With the suggested specialty courses and associated competencies, course descriptions, outlines and laboratory activities were written for each course. The courses were divided into subunits that dealt with one aspect of the course subject--these subunits formed the basis for the module outlines that were developed. Each module taught one part of a course; by having courses taught in modular units, students recognize their progress and achievement more readily.

The course and module outlines were proposed to the POE at the third meeting. Several comments were made concerning the outlines--in fact, the second module in Controllers for Robots and Automated Systems was retitled and completely rewritten during the meeting. The changes recommended were incorporated prior to submitting the outlines to reviewers.

Simultaneously with the effort relating the required competencies to core and specialty courses, an analysis was performed on the Unified Technical Concepts physics courses. The fundamentals needed to support the core and specialty courses should be taught in UTC Physics. To provide this knowledge, eight existing experiments require modification and five new experiments need to be written as explained below:

1F3 LINEAR ACTUATOR CYLINDER

Change: Add cylinder

The hydraulic cylinder is a device commonly used to move heavy objects. It uses the principle of transforming controlled hydraulic pressure into linear force. In this module, the student will be introduced to operating principles of hydraulic cylinders and the interrelated role of hydraulic pressure and force in the operation of cylinders.

2F1 WORK BY FLUID PUMPS

Change: Add hydraulic pumps

Students review the principles of work and energy as they apply to fluids and electricity. Values for work and energy involving fluids and electricity are determined both experimentally and by calculation. In the laboratory, students measure electrical power input and hydraulic power output of a motor/pump.

3M7 SPHERICAL MOTION

New experiment

Students will expand their previous study of motion in two dimensions into three dimensions. Linear and rotational motion (velocity and acceleration) will be evaluated as they occur in normal working environments. Students will measure and calculate relative positions of points in spherical coordinates.

4M1 ANGULAR MOMENTUM

Change: Revise to add single mass

In this module, the student will examine the concept of angular momentum. Angular momentum of several rotating systems will be calculated. In the laboratory, the angular momentum of a flywheel and a single mass will be measured by two techniques and the results compared.

5M1 FRICTION

Change: Add gripper experiment

This module explains some of the factors that influence friction. It also includes a demonstration of a method to calculate frictional forces between one or two pairs of surfaces in contact.

7F4 ENERGY CONVERSION IN FLUID SYSTEMS

Change: Add application

Energy has been defined as the capacity to do work. Also, energy cannot be created, but energy may be transferred from one form to another within a system.

Potential energy, the capacity to do work because of position, may be transferred to kinetic energy, the capacity to do work because of motion. This module will demonstrate this energy transfer in fluid systems.

8M1 LEVERS

Change: Add application

The lever is one of the simplest and most common mechanical force transformers. Depending upon its configuration, the lever may be used to amplify either force or displacement, or to change their directions.

In this module, the student will investigate the lever as a force transformer. In the laboratory, the student will measure and calculate the mechanical advantages of several levers.

9F5 VACUUM PUMPS

Change: Add application

A number of different pumps are used to produce a vacuum in enclosed chambers. These pumps include rotary mechanical pumps, diffusion pumps, sputter-ion pumps, and cryogenic pumps. The pressure ranges that can be covered vary from one pump type to another. In common practice, a mechanical pump is used to pump down from atmospheric pressure to medium vacuum; and then a second pump is switched on to reach high or ultrahigh vacuum.

In the laboratory, the student will use at least two different pump types to evacuate a vacuum system and will measure the pressure in the system during pump-down.

9E6 PRECISION CONTROL MOTORS

New experiment

This module introduces students to electric motors whose movement is controlled by input pulses--stepper motors. Rotor position is controlled by the number of input pulses, allowing accurate positioning of mechanisms operated by the motors.

10E2 HALL-EFFECT DEVICES

New experiment

Students will learn how changes in magnetic fields can be used to sense the position or attitude of various items. A change in magnetic field, or the introduction of a magnetic field, will be evaluated as a control for other electronic circuitry.

10E3 PIEZOELECTRIC DEVICES

New experiment

There are materials that, when acted upon physically or thermally, generate electrical signals that can be detected, amplified and used to sense various parameters. Students will study the operating characteristics of piezoelectric devices in the laboratory.

11M3 VIBRATION ISOLATION

New application

Mechanical vibrations are produced by almost every kind of machinery. Electric motors, internal combustion engines, air compressors, vacuum pumps, printing and manufacturing presses, and fans all produce unwanted vibrations. If these vibrations are not eliminated or reduced to an acceptable level, they can destroy the machinery or limit its proper operation.

In this module the characteristics of steady-state vibrations will be illustrated, and the methods used to eliminate or reduce these vibrations in various kinds of machinery will be discussed. In the laboratory, the student will measure the acceleration of a vibrating system and its support to determine transmission of vibration.

13L18 ENCODERS/RESOLVERS

New experiment

Students will study the concept of controlling electric motor speed and rotor position by counting photoelectric signal pulses. Position sensing of this type is being used as part of control systems in robotics and automated systems to monitor the operation of various machines.

TASK H--REVISE AND REVIEW NEW MODULE OUTLINES

After comments provided by the POE had been incorporated, course and module outlines were submitted to ten persons--experts in robotics and automated systems--for review. The list of reviewers, approved by the Department of Education, is included in Appendix F to this report. Several reviewers submitted suggested changes and questions--others said the curriculum, courses, and modules were excellent without change.

Based upon these inputs, changes were incorporated; those that were not incorporated were discussed with the reviewer to explain the rationale. The modified--and final--course descriptions and module outlines are included in Volume 2.

CONCLUSIONS AND RECOMMENDATIONS

Research efforts in the early phases of this project indicated that a significant difference existed between the education/training requirements for Robotics/Automated Systems Technicians and the content of established programs at public institutions. An assessment of employer requirements provided evidence of need for a broad, interdisciplinary technician with a sound base in technical fundamentals, capable of learning new technology and devices as they emerge. Many of the existing programs at schools reflected the traditional approach to a narrow, highly specialized "training" program, providing only skills and techniques on existing equipment. These type programs were preparing robotic "operators" instead of technicians.

Through increased efforts in project awareness and the intense participation of the project staff in professional organizations (such as RI/SME, AVA, ASEE, etc.), the curriculum model developed by this project has become firmly established as the guideline for excellence in this technological area. The focus of this project has had timely and significant impact in realigning existing technician programs and the creation of new programs in robotics and automated technology. It is regrettable that the project was not conducted 18 months earlier so that many of the existing institutional programs in this field could have been altered before significant resources had been expended.

RECOMMENDATIONS

1. Develop modular instructional materials to support the six specialty courses in the RAST curriculum. Numerous textbooks on robotics are being produced, but they all attempt to present the entire content of the six courses in one text. What is needed is complete, competency-based, instructional materials for each course. The project staff is attempting to secure funding for the development of appropriate material.
2. Similar curriculum projects are urgently needed to provide national models for technician education/training on other emerging, advanced-technology areas:

a. CADD/CAM

b. Biotechnology

c. Instrumentation/Control

d. Telecommunications

Curriculum models in these areas must be developed by staff with appropriate expertise, so that the content will have sufficient depth and credibility to command acceptance.

The consequences of not providing substantial national leadership in these areas will be a repeat of history where local schools may waste valuable resources to implement misdirected programs because they cannot devote sufficient research and do not have a national model from which to work.

APPENDIX A

Visibility Activities

1. News Release Requests
2. *Robotics Today* Announcement
3. State-of-the-Art Newsletter
4. *Robotics Age* Announcement
5. Direct Inquiries

CORD CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT
601 C Lake Air Drive Waco, Texas 76710 Telephone (817) 772-8756

September 8, 1983

Newsrelease Assns.

Dear File:

The Center for Occupational Research and Development (CORD) has received a Robotics Technician Task Analysis contract from the United States Department of Education. The contract is briefly described in the enclosed "News Release."

To notify the public of this contract, CORD would appreciate your including an announcement describing/paraphrasing the information (in the News Release) in your periodicals.

Thank you for your cooperation.

Sincerely,

James E. Lovett
Research Associate

JEL:pt
Enclosures

Ms. Mary Paris
NSPE Publications
Engineering Times
2029 K Street NW
Washington, DC 20006

Ms. Sue Lomote
American Society of Engineering Education
11 DuPont
Suite 200
Washington, DC 20036

Mr. Robert N. Stauffer
Editor - Robotics Today
Society of Manufacturing Engineers
P.O. Box 930
Dearborn, MI 48128

Ms. Garbiel Wacker
American Vocational Association
2020 North Fourteenth Street
Arlington, VA 22201

INDUSTRY NEWS

ELLEN J. KEHOE, Assistant Editor

14TH ISIR SET FOR SWEDEN OCTOBER 1984

Gothenburg, Sweden, is the setting for the 14th International Symposium on Industrial Robots (ISIR) and the 8th International Conference on Industrial Robot Technology, to be held October 2-4, 1984. In conjunction with the symposium will be the biannual exhibition "Scanautomatic," covering industrial automation. The theme of the show is "Industrial Robot Systems: Progress in Production," with emphasis on robots as key elements in total manufacturing systems, particularly in view of the human and economic aspects

Again in 1984, the Robot Institute of America (RIA) will sponsor a tour open to U.S. attendees. For more information on the tour, contact Lori Lachowicz, manager of RIA, at (313) 271-0778.

BURNSTEIN NAMED PR MANAGER OF RIA

Jeffrey A. Burnstein has been named Manager of Public Relations for the Robot Institute of America (RIA). Burnstein spent the last two and a half years as Assistant Manager of Public Relations for the Society of Manufacturing Engineers.

RIA has over 200 members including leading robot manufacturers, distributors, corporate users, and accessory equipment suppliers.

CURRICULUM GRANT

An 18-month contract to design and develop a national curriculum model for training robotics technicians has been awarded to the *Center for Occupational Research and Development* (CORD), Waco, TX, by the U.S. Department of Education. The project includes a task analysis of robotics and automated manufacturing technicians, design of a model curriculum, preparation of material to support robot specialty courses and laboratories, and an evaluation of existing training materials and programs.

For evaluation in this study, CORD is requesting information on programs currently being taught. To send information, or to receive a copy of the final report, contact Jim Lovett at CORD, 601 C Lake Air Dr., Waco, TX 76710, or telephone (817) 772-8756.

PEOPLE

Ian A. Barrie to vice president and general manager at the *Ontario Robotics Centre.*

Thomas W. Kludt to senior engineer and manager of the *IBM Robotic Assembly Institute.*

Joseph Carcone to manager of vision systems marketing for the Intelligent Vision Systems operation of *General Electric.*

John F. Logan to vice president—marketing and commercial sales and **Arthur L. Anderson** to regional sales manager at *Automated Robotic Systems, Inc.*

James N. Perry to general manager—robotics at *Schrader Bellows,* a division of Scovill, Inc.

John R. Anderson to vice president, marketing and sales; **Irv Burough** to manager of engineering; and **Stan Truitt** to manager of research and development at *Syn-Optics.*

George Miller has been named general manager of the Denver operations division, *FARED Robot Systems, Inc.*

Richard E. Rinehart to director of marketing for *ASEA Robotics.*

CORD CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT
601 C Lake Air Drive Waco, Texas 76710 Telephone (817) 772-8756

News Release:

ROBOTIC EDUCATION

The Center for Occupational Research and Development has received a contract from the United States Department of Education to design and develop a national curriculum model for training technicians in Robotics and Automated Manufacturing Technology. The 18 month project, beginning in late August 1983, includes preparation of a Task Analysis of Robotics Technicians, design of a model curriculum for postsecondary technical institutions and community colleges, preparation of module outlines to support Robot specialty courses and laboratories, and an evaluation of existing training materials and programs in this rapidly growing area.

The attached Preliminary Fact Sheet describes pertinent data concerning the specific tasks to be accomplished.

To ensure the consideration of all existing curriculum and course material, CORD is requesting copies of curricula, course descriptions, and bibliographies of programs currently being taught. Also, to facilitate broad disbursement of information collected and refined, any company, institution, or individual wishing to receive the final report should contact CORD. Please send information to or contact Jim Lovett, Center for Occupational Research and Development, 601C Lake Air Drive, Waco, Texas 76710, (817)772-8756.

A Nonprofit Public Service Corporation

CORD CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT

601 C Lake Air Drive Waco, Texas 76710 Telephone (817) 772-8756

June 28, 1984

Dr. James Gollattscheck
Editor-in-Chief
American Association Community &
Junior Colleges
One DuPont Circle, NW
Washington, DC 20036

Dear Dr. Gollattscheck:

The Center for Occupational Research and Development is currently working on a United States Department of Education contract to develop a model curriculum for training Robotics/Automated Systems Technicians. One important outcome of this project is a report that defines current state-of-the-art training for these technicians in the United States. This report has been completed and is available as described in the accompanying News Release.

Please include in your journal an announcement similar to the enclosed News Release. Thank you for your cooperation.

Sincerely,

James E. Lovett

James E. Lovett
Research Associate

JEL/ad
Enclosure

CORD CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT
601 C Lake Air Drive Waco, Texas 76710 Telephone (817) 772-8756

June 28, 1984

Mr. Bob Stauffer, Editor
Robotics Today
Society of Manufacturing Engineers
P.O. Box 930
Dearborn, MI 48121

Dear Mr. Stauffer:

The Center for Occupational Research and Development is currently working on a United States Department of Education contract to develop a model curriculum for training Robotics/Automated Systems Technicians. One important outcome of this project is a report that defines current state-of-the-art training for these technicians in the United States. This report has been completed and is available as described in the accompanying News Release.

Please include in your journal an announcement similar to the enclosed News Release. Thank you for your cooperation.

Sincerely,

James E. Lovett

James E. Lovett
Research Associate

JEL/ad
Enclosure

CORD CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT

601 C Lake Air Drive Waco, Texas 76710 Telephone (817) 772-8756

June 28, 1984

Mr. Raymond Cote, Editor
Robotics Age
174 Concord St.
Peterborough, NH 03458

Dear Mr. Cote:

The Center for Occupational Research and Development is currently working on a United States Department of Education contract to develop a model curriculum for training Robotics/Automated Systems Technicians. One important outcome of this project is a report that defines current state-of-the-art training for these technicians in the United States. This report has been completed and is available as described in the accompanying News Release.

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Sincerely,

James E. Lovett

James E. Lovett
Research Associate

JEL/ad
Enclosure

A Nonprofit Public Service Corporation

ORD CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT
601 C Lake Air Drive Waco, Texas 76710 Telephone (817) 772-8756

June 28, 1984

Ms. Gladys Santo
American Vocational Assocation
200 N. 14th St.
Arlington, VA 22201

Dear Ms. Santo:

The Center for Occupational Research and Development is currently working on a United States Department of Education contract to develop a model curriculum for training Robotics/Automated Systems Technicians. One important outcome of this project is a report that defines current state-of-the-art training for these technicians in the United States. This report has been completed and is available as described in the accompanying News Release.

Please include in your journal an announcement similar to the enclosed News Release. Thank you for your cooperation.

Sincerely,

James E. Lovett

James E. Lovett
Research Associate

JEL/ad
Enclosure

CORD CENTER FOR OCCUPATIONAL RESEARCH AND DEVELOPMENT
601 C Lake Air Drive Waco, Texas 76710 Telephone (817) 772-8756

NEWS RELEASE

The Center for Occupational Research and Development (CORD) has completed preparation of a "State-of-the-Art" Report describing current training of Robotics/Automated Systems Technicians in the United States. The report includes listings of the two-year postsecondary schools that offer Robotics/Automated Systems Technician training, those schools with baccalaureate and graduate training in robotics and a list of texts currently in use at the various schools. Also included is a needs assessment of programs and materials required to adequately train technicians to operate and maintain tomorrow's robots and automated systems.

The report can be ordered from CORD, 601C Lake Air Drive, Waco, Texas 76710; the cost is $12.50 plus postage.

Sensory Perceptions

ROBOT TESTIMONY. For the first time in history, a personal robot testified before members of the US House of Representatives. On May 22, RoPet-HR, manufactured by Personal Robotics Corp., testified before the House Select Committee on Aging, chaired by the honorable Edward Roybal (D-Los Angeles), to demonstrate its safety benefits to the elderly. RoPet-HR showed some of its abilities by detecting a passerby and activating a built-in alarm when it did not receive the correct spoken response, adding that it would soon set off a remote alarm or phone for assistance.

Projected capabilities include detecting the word "Help," dialing the police emergency number, and then homing in on the person and acting as a two-way telephone system. At present, Personal Robotics Corp. is working with the Palo Alto Veterans Administration Hospital on this project and others. For more information, contact: Personal Robotics Corp., 469 Waskow Drive, San Jose, CA 95123.

OLYMPIC RESULTS. More than 15 Southern California schools captured awards at the Robot Olympics held at Cal State, San Bernardino on April 27-28. The games gave students ranging from elementary through high school, an opportunity to demonstrate their computer and robot programming skills. Students programmed such computers as the Big Trak, Turtle Tot, and Hero I, in competitive events including figure tracing and traversing a maze. Student teams raced across the clock to construct a Memocon Crawler robot from a sealed kit against the clock.

Mission Junior High School took the first place trophy in the robot construction event, building a functional robot in 26 minutes and 20 seconds. All schools finishing in other events such as the robot biathlon and robot slalom were awarded trophies. Robot programming events included figure tracing, robot slalom, robot biathlon, and the robot dash.

FORT WORTH RESEARCH CENTER. Business and civic leaders have begun a campaign to raise $10 million in funding to create the Advanced Robotics Research Institute, a high-tech center to be located in Fort Worth and staffed by the engineering department of the University of Texas at Arlington.

The Institute will provide a center for research into practical applications for the newly-emerging science of robotics and artificial intelligence. In addition to studying new areas of application, the engineering team will work with robotics manufacturers and plant owners who use equipment to increase productivity. The staff of robotics experts has been assembled by Dr. John W. Rouse, dean of the UTA School of Engineering, and will be supplemented with visiting professors as well. The building is scheduled for completion in 1985.

TRAINING REPORT. The Center for Occupational Research and Development (CORD) has completed preparation of a state-of-the-art report describing current training of robotics/automated systems technicians in the United States. The report includes listings of two-year post-secondary schools that offer robotics/automated systems technician training, those schools with baccalaureate and graduate training in robotics, and a list of texts currently in use at the various schools. Also included is a needs assessment of programs and materials required to adequately train technicians to operate and maintain tomorrow's robots and automated systems. The report is available from CORD, 601C Lake Air Drive, Waco, TX 76710.

NBS AND WESTINGHOUSE JOIN FORCES. The National Bureau of Standards and Westinghouse R&D Center are beginning a joint research program to study robot control techniques capable of managing a robot for close-tolerance parts-matching and for work in concert with a second robot. The project will be based on NBS-developed real-time control systems for robots. Researchers will work on control systems to be used in an automated parts cleaning and deburring station in the NBS Automated Manufacturing Research Facility. This work station will feature the cooperative action of two robot arms working under a common system.

THE ROBOT CONSTRUCTION GAME. If you're looking for a way to demonstrate the

LIST OF DIRECT INQUIRIES CONCERNING
ROBOTICS/AUTOMATED SYSTEMS TECHNICIAN TRAINING PROJECT

Mr. Larry G. Owen, Director
Technical Engineering Division
South Arkansas University Tech

Mr. Q. Quigley
Major Appliance Instructor
California Correctional Institute
at Tehachapi

Ms. Marilyn Sullivan, President
Colorado Technical College

Mr. Sid Burks, Director
Technical Education
National Education Corporation

Mr. Francis Redmore
Drafting Chairman
Cartland-Madison BOCES

Mr. J. D. Mueller
Associate Dean of Instruction
Director Occupational Tech Programs
Texarkana Community College

Professor Parthy Iyengar
Mechanical Engineering Tech Dept
County College of Morris

Mr. Russell Shellhammer, Supervisor
Adult Continuing Education
Somerset County Technical Institute

Mr. Bud Zahary
Director Continuing Education
N. Alberta Institute of Technology

Mr. Gary Mickolajak, Dean
Vocational Education
Central Arizona College

Mr. Robert Applebaum
Control Data

Mr. W. J. Russell
Acting Chairman
Community College of Rhode Island

Mr. Bruce Ottens
Owens Technical College

Mr. Glenn Artman, Asst Prof
Robotics & Auto Mfg
Delaware County Community College

Mr. Leonard Smits, Instructor
La Comission des Ecoles
Catholiques de Montreal

Mr. Earl Tickler, C. E. T.
Director of Instruction
RETS Electronic Schools

Mr. Glen Schrock
Department Head
Industrial Technology
Hawkeye Inst of Technology

Mr. Bill McMillan
Technology Department
Grand Rapids Junior College

Ms. Chris Prunier
Massachusetts Career Dev Inst

Mr. Thomas J. Meravi
Associate Professor
Northern Michigan University

Mr. Steve Dickerson
Assoc Dir of Mech Engineering
Georgia Institute of Technology

Mr. Robert Dixon
Dept Chairman-Engineering
Portland Community College

Mr. Bruce Ottens
Owens Technical College

Dr. William D. McLean
Dean, Livingston Campus
Cleary College

Mr. Don Krummel, Coordinator
Manufacturing Department
Waskesha County Technical Institute

Mr. Wayne Anderson
Robotics Instructor
Granite Falls AVTI

Ms. Mary Martin
Director of Grants
Tri-County Technical College

Mr. Patrick Terrel
Training & Safety Coordinator
Northern Telecom, Ltd

Mr. Mark Barnard
Millicom, Inc

Ms. Wanda Marrs
Tech Trends, Inc

Mr. Donnie C. Hoops
Career Education Director
Medina County Vocational Center

Mr. Gary Bazinet
University of South Maine

Barry Noonan, PhD
Dean of Instruction
Red Rocks Community College

Mr. Jack Phillips
Katy, TX

Mr. Dave Claeys
Scott County Community College

Mr. Ken Anthony, Instructor
Technical Training Department
Oldsmobile-Division of
General Motors Corporation

Mr. Robert Lykens, Principal
Kent North Voc-Tech High School
Dover, DE

Mr. David Carroll
Assistant Director
Staples Technical Institute

Mr. Jack Miller
Dean, Business & Technology
Mount Hood Community College

Ms. Marilyn O. Sullivan
President
Colorado Technical College

Mr. Bob Dorn
Territory Manager/Robotics Systems
General Electric

Mr. Nick Ciolfi
Program Coordinator
Niagara College

Mr. R. Chatterjee
Centennial College of Applied
Arts and Technology

Mr. C.L. Ziegler, PE
Chairman, Engineering Technology
University of Toledo

Mr. Dawain Riebow
Technical Instructor
Oldsmobile Division of GM

Mr. Milton Calopach
Indianapolis, IN

Mr. Michael Crawford, Chancellor
Eastern Iowa Comm College Dist

Ms. Rita Noel
Vo-Tech Project
Southern Illinois University

Mr. Henry Horwitz
Dutchess Community College

Mr. Rick Ross
Scott County Community College

Mr. Ben Burdick
Rock Springs, WY

Ms. Anne Jorgenson
San Diego, CA

Mr. Ben Nagler
Automation News

Mr. Jim Lancaster
Lanshaw & Co

Dr. C. Spence, President
Clinton Community College

Mr. Erhan Ilksoy
Gwinnett Area Technical School

Ms. Diane Frozer
El Paso Community College

Prof Charles Taylor
Western State College of Colorado

Mr. Jim Clark
Waukesha Technical Institute

Mr. Wayne Anderson
Granite Falls AVTI

Mr. Don Krummel, Coordinator
Waukesha County Technical Inst

Mr. Harold Markenet
Dodge City Community College

Ms. Becky Dickerson
Capitol Publishing Co.

APPENDIX B

Information Activities

1. Project Fact Sheet
2. Project Brochure
3. Paper--"A National Model for Training Robotics/Automated Systems Technicians"
4. Paper--"Robotics/Automated Systems Technician Training in the U.S.A.--A State-of-the-Art Report"
5. Paper--"Education for Robotics/Automated Systems Technicians"

FACT SHEET
TASK ANALYSIS AND DESCRIPTIONS OF REQUIRED JOB COMPETENCIES OF ROBOTICS TECHNICIANS

Contract 300830122 Duration: August 22, 1983 - February 21, 1985
Contractor: Center for Occupational Research and Development
Project Director: Daniel M. Hull USED Project Officer: Paul Geib

BACKGROUND AND NEED

Robotics and automated manufacturing have become subjects of special interest to industry. They are seen as effective technologies for increasing production and quality. The installation of robots in the industrial workplace will help manufacturing problems associated with: (a) work in hazardous atmospheres; (b) jobs that have a high personal risk; and (c) tasks that are routine, repetitive, and boring.

To install and incorporate robots in normal production, industry needs an increasing supply of special technicians. These technicians need training in basic technical fundamentals and in specific robotics technology, tasks and applications. Schools need to develop appropriate training programs for the preparation of competent robotics technicians.

PROJECT PURPOSE

The purpose of this project is to generate a model curriculum and module outlines to support the courses identified in the curriculum. At the conclusion of the project information will be disseminated nationally to educational institutions to describe the results and availability of the material developed.

MAJOR ACTIVITIES

CORD will, during the course of the contract, develop (a) statement of the current state of the art in robotics; (b) task analyses of jobs performed; (c) detailed list of competencies; (d) model curriculum; (e) new/revised module outlines for courses in the model curriculum; and (f) a list of required laboratory equipment. The above items will be developed and presented to the Panel of Experts (POE) for review and concurrence.

The POE will meet formally as a body three times. In addition, they will be called upon individually and informally--through mailings--to review work in process.

The CORD staff will describe the project through white papers and appropriate public presentations as opportunities occur.

PROJECT DELIVERABLES

The following deliverables will be made available to the public:

- Model Curriculum
- Course/Module Outlines
- Required Laboratory Equipment
- Product Report

IMPACT

This project will make available to schools a model curriculum for a technician-oriented Robotics/Automated Manufacturing Program with material to support its installation. The adequacy of the curriculum and material will be evidenced by the ease with which schools implement Robotic/Automated Manufacturing Programs.

Project Operation and Goals

While the project is managed by CORD, a panel of experts has been selected to guide the progress and ensure the usefulness of the curriculum and module outlines. This panel is comprised of nationally recognized persons involved in robotics/automated systems manufacturing, applications, training and labor.

The products of the project include:

- A report cataloging the schools and text materials involved with Robotics/Automated Systems Technician training. It includes information concerning the content and intensity of specific training and an estimate of the number of graduates in the next five years.
- A comprehensive list of job competencies for which a Robotics/Automated Systems Technician should be trained.
- A model curriculum for Robotics/Automated Systems Technician training. It will include course descriptions, student competencies, objectives, course/module outlines, and facility and equipment descriptions.

The Center for Occupational Research and Development is a nonprofit corporation that conducts research, development, evaluation, and dissemination activities in postsecondary education and training for technical occupations. CORD identifies workforce needs in new and expanding occupations and develops program plans and instructional materials to be used by two-year institutions that provide specialized training for these occupational needs or by employers in industrial training programs. CORD conducts its activities in cooperation with selected educational institutions, government agencies, and industrial organizations throughout the United States.

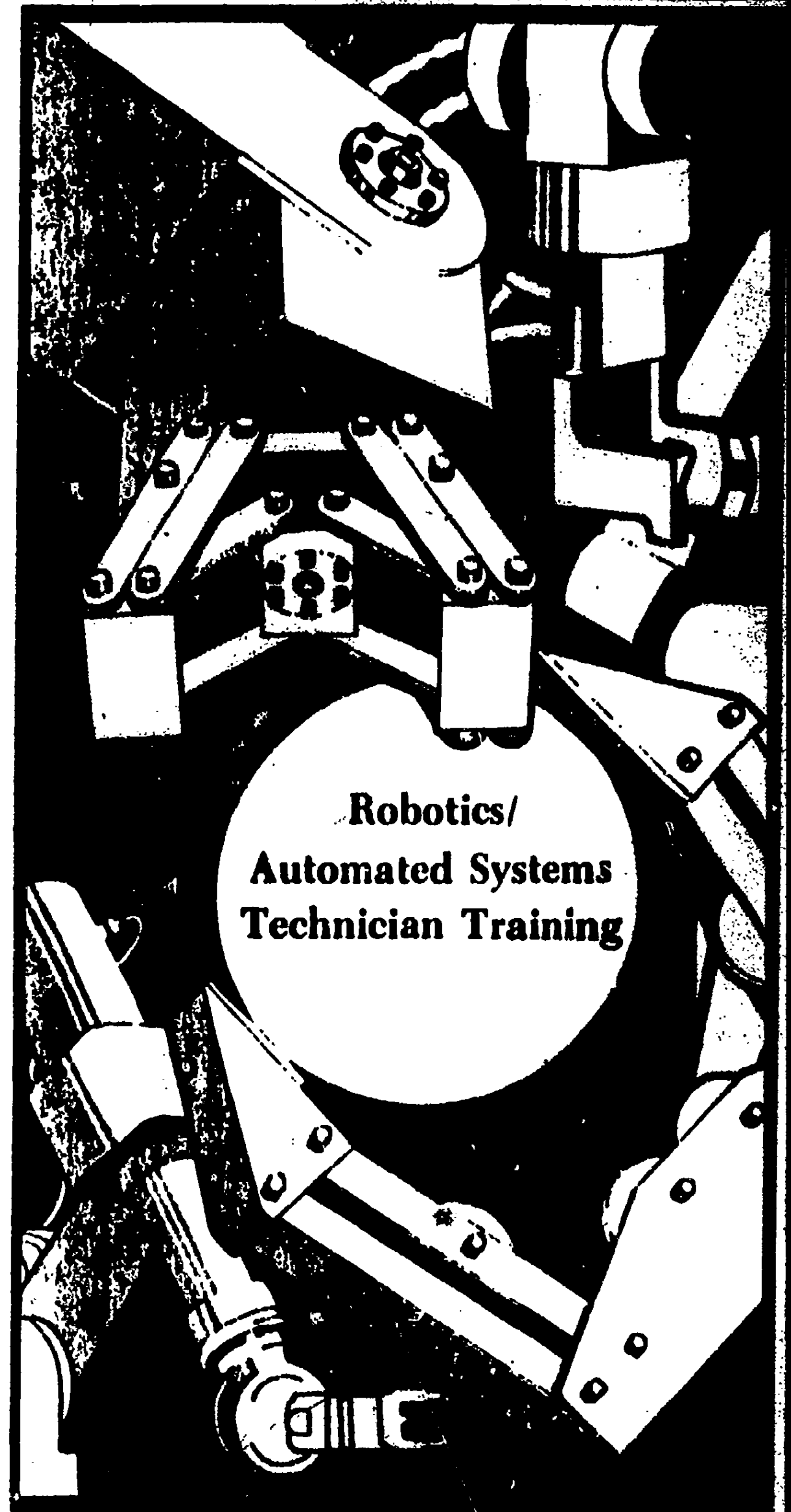
Once programs and materials have been developed, CORD assists schools and industry in implementing the programs and adapting them to meet local needs.

For specific details about CORD services or the availability of Robotics/Automated Systems reports and curriculum information, please contact Jim Lovett.

CORD

Center for Occupational Research and Development

800 231-3015
Waco, Texas 76710



Automation . . . the key to productivity

Automated systems are the answer to future economical production. As robots and automated systems are incorporated into industrial facilities, competent technicians will be required to install, operate, maintain and repair them.

Previously, highly trained engineers have been assigned the duties of Robotics/Automated Systems Technicians. To maximize the efficiency of personnel, there is an immediate need to return those engineers to their areas of specialty. This can only be accomplished by hiring qualified technicians specifically trained to work on and with robots and automated systems.

Robotics/ Automated Systems Technician

Robotics/Automated Systems Technicians are technical specialists with broad-based electromechanical skills, including electronic, mechanical and hydraulic/pneumatic devices. They are usually specialists in automated manufacturing or processing equipment and can set up robots which work together as part of a total automated system. In their area of specialization they can install, set up, troubleshoot, integrate, program, modify, test, operate and repair systems and components. They are field service, installation or service technicians. They will work either under the supervision of an engineer, as a member of a team or as a supervisor of other technicians.

Tasks

Many employers indicate that Robotics/ Automated Systems Technicians will work under the direction of engineers and scientists. Others say they would employ technicians capable of working either independently or in teams to develop, construct, install, test, operate, and maintain robots and automated systems. Possible tasks required of the technicians include:

- Measure robot performance – positioning and accuracy
- Adapt welders, paint sprayers, and grinders to robots
- Install, set up, and calibrate data transmission systems
- Install, program, and repair programmable controllers
- Disassemble, repair, install and test robots
- Set up robots to work together as part of automated systems
- Troubleshoot, test, repair and adjust complete automated systems

National Model Curriculum

The Center for Occupational Research and Development/CORD has been contracted by the United States Department of Education to develop a national model curriculum for Robotics/Automated Systems Technician training. The two-year, postsecondary curriculum will be based upon job competencies/task lists that identify the specific functions of these technicians.

The project includes the development of course outlines; the courses will be modular, allowing students to easily recognize the achievement of learning skills. CORD will prepare module outlines as part of the project, then complete module preparation with private funds.

TECHNICAL PAPER

MS84-419

A National Model for Training Robotics/Automated Systems Technicians

abstract

Education programs for robotics technicians in the United States today are needed to keep pace with rapidly expanding use of robots. Carefully trained technicians are needed to troubleshoot, repair, adapt, interface, and assemble/disassemble the different types of robots. The United States Department of Education has issued a contract to develop a national model curriculum for robotics technicians. The Center for occupational Research and Development (CORD), as contractor, has already established prototype, broad-based technical core curricula for high-technology programs. CORD, under guidance of a panel of experts, is adapting the technical core prototype and designing special robot courses to meet requirements for robotics technicians. In the process, CORD will perform task analyses, develop required competencies, identify specific courses required and prepare needed course outlines. Results of the 18-month project will be available to institutions that are establishing new robotics programs or modifying existing robotics programs. Robot competencies, task analyses, and education curriculum—technical core and specialty courses—that CORD is developing for the national model curriculum are discussed.

authors

DANIEL M. HULL
President
Center for Occupational Research and Development
Waco, Texas

JAMES E. LOVETT
Research Associate
Center for Occupational Research and Development

conference

Robots 8 Conference
June 4-7, 1984
Detroit, Michigan

index terms

Robots
Education
Engineering Education
Training

1984

Society of Manufacturing Engineers • One SME Drive • P.O. Box 930
Dearborn, Michigan 48121 • Phone (313) 271-1500

SME TECHNICAL PAPERS

BEST COPY AVAILABLE

Manufacturing organizations across the country have retooled and modernized their facilities and equipment. As a consequence, they have discovered that their requirements for a technical workforce have also changed. Fifteen years ago, the technical skill mix generally consisted of engineers, draftsmen, mechanics, electricians, and assemblers. Today the technical skill mix requires engineers, technicians, CAD operators, operators of semiautomated and automated equipment, and perhaps a few assemblers. It appears that fewer mechanics and electricians will be required. Studies by Battelle-Columbus Laboratories[1] and others indicate that modern manufacturers, using high-tech equipment, will require more engineers, technicians, and operators, but will use fewer craft workers. Recent experience gives clear evidence of significant displacement of workers in jobs involving assembly, welding, conventional machining and others. This workforce trend is shown graphically in Figure 1.

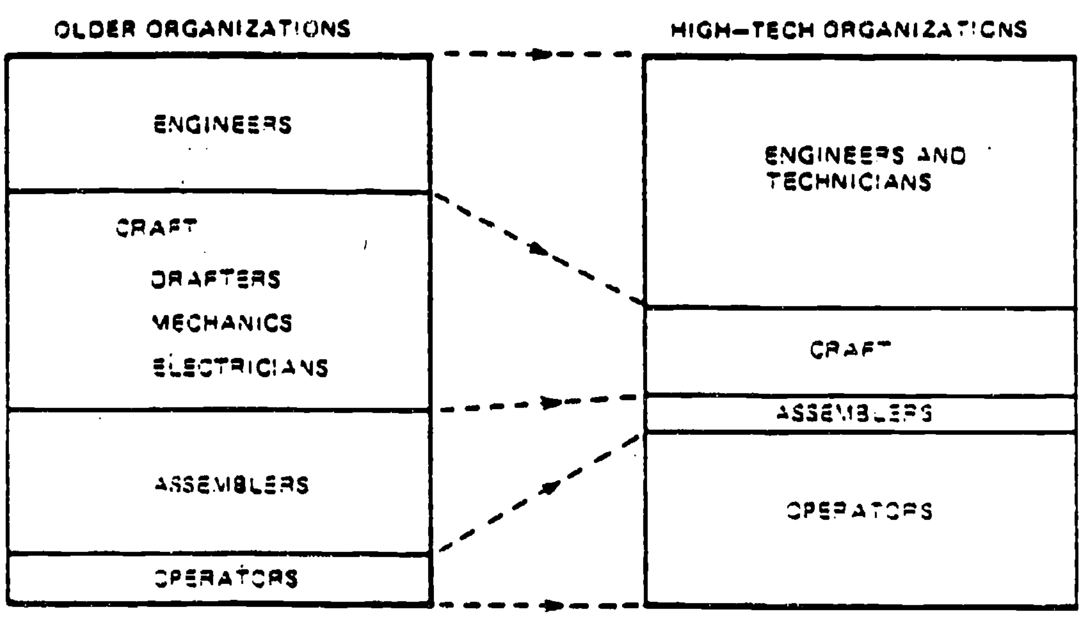


Fig. 1 Changes in the technical skill mix required in modern manufacturing.

The role of the semiprofessional technical worker is emerging very rapidly in manufacturing organizations. This worker has relieved the engineer of the more routine and hands-on tasks and has assumed the maintenance function on complex, modern, automated production equipment. This maintenance requires more knowledge than electricians and mechanics possess in electromechanical fundamentals, automated manufacturing equipment and processes, material properties and computer hardware software. The modern manufacturing technician that we are describing here is no longer the narrow specialist in electronics or computers. This technician approaches a generalist, with a broad base in electrical/electronics, mechanical, fluid, thermal, and optical fundamentals and devices--a technician with a systems orientation. The

[1] Development of High Technology Industries in NY State. Columbus, OH. Battelle-Columbus Laboratories, April 1982.

desirable characteristics of the "super-techs" that we are identifying are described in Figure 2.

"SUPER-TECHS" FOR HIGH TECHNOLOGY

- **SYSTEMS ORIENTED**
- **COMBINATION OF SKILLS — INTERDISCIPLINARY**
  - ELECTRICAL
  - MECHANICAL
  - FLUIDAL
  - THERMAL
  - OPTICAL
  - MICROCOMPUTERS
- **STRONG TECHNICAL BASE**
  - CAPABLE OF LEARNING NEW SPECIALTIES AS THE TECHNOLOGY CHANGES

Fig. 2 Super-techs for high-technology manufacturers.

Modern technicians are being asked to work on jobs that lie somewhere between those attended to by craftspersons and operators on one end of the scale--and engineers on the other end. Technicians may well need to perform skill-type tasks, operate machinery, or interpret customer specifications. A job description recently developed for a Robotics/Automated Systems Technician indicates the breadth of talents and skills required:

> Technicians are technical specialists with broad-based electro-mechanical skills who are familiar with electrical, electronic, mechanical and hydraulic devices. They are usually specialists in one or two identifiable types of specialty equipment. In their area of specialty, they can install, set up, troubleshoot, repair/replace parts, modify, test and operate the equipment. They may work either under the supervision of an engineer, as a member of a team, or as a supervisor of other technicians.

Currently, technicians are required to be familiar with a wide variety of systems and devices--and to work on most of them. Their responsibilities involve installation, setup, calibration, test, and operation of new equipment. This equipment may be powered by hydraulic, pneumatic or electrical systems. To be affective, the technician will have to read, understand, and interpret manufacturers' operators/maintenance manuals and drawings. The modern technician may have to isolate, identify and repair or replace failed or damaged devices.

It seems then, that there will be little or no limitation--within a specialty area--of the equipment on which a technician will work. For example, Robotics Technicians will be expected to work on all types of systems--electrical, hydraulic and pneumatic--that operate robots. In addition they will need to be familiar with programming, computers, microprocessors, programmable controllers, grippers, vision systems, and many more. A technician will have to know how sensors, solenoids, relays, power supplies, dc motors, servosystems, pumps, valves, and safety devices operate individually and, when assembled, how they contribute to system operation.

Some of the greatest concerns in technician training for the future involve answers to the following questions: "What equipment, systems and components will there be? What new, currently unknown or undeveloped ideas will come to fruition and confront tomorrow's technicians?" For example, let's consider these questions for the rapidly developing area of robotics. If one traces the development of robot sophistication and complexity over just the past several years, one finds startling improvements in tactile sensing, off-line interfacing, introductions of electronic assembly robots, adaptive controls, and the application of robots to aerospace construction and the manufacture of composite materials. At the same time robots are being used increasingly in undersea, space and agricultural applications. Could this movement of technology have been predicted five years ago?

Robotics systems that are currently being developed include vision--recognition of randomly-stacked, odd-shaped, various-shaped parts--artificial intelligence--the level of "thought" or decision-making capabilities--and sensors--how a robot can recognize, by touch, what the orientation of a part is. These will in all likelihood be part of the development in the next one to five years. What will the research areas be in the next five years?

ROBOTS VERSUS AUTOMATED MANUFACTURING SYSTEMS

While robots are wonderful machines and very useful tools, they are only one part of a manufacturing system. A robot standing in the middle of a room can't do a thing without the help of either humans or automated equipment.

Robots and Automated Manufacturing Systems are names applied to different assemblies of similar components. If one were to disassemble a robot one would find hydraulic, pneumatic, electrical and/or electronic systems. These systems would consist of valves, pumps, motors, switches, relays, safety devices, sensors, and power supplies. These parts could be assembled in a variety of ways to accomplish many different tasks.

If an automated manufacturing system were taken apart and disassembled, and the components and subsystems analyzed, there would surely be hydraulic, pneumatic, electrical, and electronic systems--similar to those appearing in robots. These systems would surely consist of components very much like those found in robots--including valves, pumps, motors, switches, relays, safety devices, sensors and power supplies.

Further, robots will be required to work in consort with some other automated equipment--thus forming an automated system. A robot alone will not, for very long, be able to do useful work. Either a human, another robot or an automated machine will have to supply parts and remove parts so that the robot can continue to perform its work.

Both robots and automated systems are controlled by any of several techniques--(re)programmable controllers, fixed controllers, microprocessors, or computers. These, in turn, may be operated by remote computers.

Since robots and automated manufacturing systems are assemblies of similar components in similar systems, and both can be controlled by similar techniques, it is reasonable to include automatic manufacturing systems in the scope of Robotics Technician Training.

TRAINING REQUIREMENTS

This new generation of manufacturing technicians will likely come from two sources:

1. Existing technical workers who have been upgraded/retrained.
2. Graduates of new high-tech programs at two-year postsecondary institutions--community colleges and technical institutions.

In the past fifteen months, a large number of industrial retraining programs have emerged. Some are programs in automated manufacturing for updating engineers; others are skills-oriented courses for electricians and mechanics. In the courses for craft workers, we see the content centering around familiarization with current techniques and equipment instead of emphasis on fundamentals. We believe that teaching current skills and techniques is only a "band-aid" approach to a problem that requires "major surgery and rehabilitation." When craft workers are updated in current skills only, they may well remain craft workers who face a declining job market with skills that will be obsolete again in two-three years.

In like manner, community colleges and technical institutes are rapidly introducing courses and programs to train robotics technicians. In a survey conducted jointly by CORD and Robotics International of the Society of Manufacturing Engineers, we learned that 50 two-year postsecondary institutions in this country are offering training to prepare robotics technicians. Data from this survey has been used to estimate that approximately 3000 new technicians with robotics training will be available on the job market by 1986. As a conservative estimate, this number will grow to 5500 by 1988 and 12,000 by 1990.

Some are predicting that there will be an oversupply of robotics technicians within a few years. If schools prepare narrow specialists--and only in current employable skills--then these predictions may become realities. If they do become realities, it could be that we are mistakenly not preparing the broad, versatile technicians that modern industries need. It could be that we are, instead, continuing to glut the job market with more skills-oriented craftspersons--when available evidence shows an oversupply.

An examination of the preliminary findings of this survey[2] indicates that many of the schools are, indeed, preparing craftspersons with glorified titles like "robotics technician." The evidence to which we point shows curricula with a lack of courses in math and science, and little or no interdisciplinary preparation in the electrical, electronic, mechanical, electromechanical, fluid, thermal and optical devices. When a program teaches only about the "outside of robots" and not the "inside," there is strong evidence that the job potential of the program graduate will be limited to operator and craft jobs.

NATIONAL CURRICULUM MODEL

A national model curriculum is being developed by the Center for Occupational Research and Development under contract from the United States Department of Education. This model will be a "prototype" curriculum that school and institutional personnel can study when they are considering instituting a Robotics/Automated Manufacturing Systems Training Program.

Upon completion of the model, module outlines will be developed for courses that are included in the curriculum. There may be course material currently available. If so, it will be incorporated and used as much as possible to facilitate course implementation.

In an effort to ensure the usefulness and relevance of the program content, thirteen representatives from robot manufacturers, users, education and labor have been assembled to form the National Advisory Committee on Robotics/Automated Manufacturing Systems Technician Training. These members--all well-known for their experience in this field--are serving voluntarily.

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[2]Center for Occupational Research and Development, with data from Robotics International/Society of Manufacturing Engineers. An Assessment of the State of the Art of Curriculum Materials and a Status Assessment of Training Programs for Robotics/Automated Systems Technicians. Waco, TX: CORD, spring 1984.

The Committee has met to review the tasks and job description for Robotics/Automated Systems Technicians (RAST). This committee is--in a sense--operating almost continuously through the mail and by telephone. The Committee will continue to function throughout development of the model curriculum and the course outlines. The project is scheduled for completion in February 1985.

When the model curriculum is completed, it will be available through CORD and the U.S. Department of Education. An institution considering the implementation of a RAST training program can request and receive project information now--and the products later this year. This will provide them with curriculum guidelines for a program to train technicians in all the subjects --foreseeable today--that are required to make them valuable, versatile employees for a manufacturer. The institution, working with a local advisory committee, can then determine the appropriateness of each subject and how to tailor the curriculum to local needs. By starting with a model program and deleting those courses not needed, an institution will have a framework upon which to build a program. This method of developing and using model curricula has worked very successfully in preparing technicians in lasers, nuclear, energy management, instrumentation, and other emerging technical areas.

COMMON CORE CURRICULUM

We earlier presented the need for a broad-based, systems-oriented approach in the training of versatile technicians. The core of this curriculum design is common to many areas of technician education in which high technology is changing traditional occupations.

A broad-based, systems-oriented curriculum can be structured in two main parts: a common core and a specialty sequence. The common core, by far the larger portion, would be comprised of basic skills and a technical core, as shown in the chart on on attachment, page 1. Basic skills would include units in the following: math (algebra, trigonometry, analytic geometry); the physical sciences; human relations and the socioeconomic factors that affect most jobs; technical communications (in speech and writing); and computer literacy (including typing or keyboarding).

The second part of the common core is a selection of technical subjects that include the following: electrical and electronic devices, mechanical devices, electromechanical devices, fluid devices, heating and cooling devices, optical devices, and microcomputers. It is this part that provides the technician with the broad-based technical core. Course descriptions of the technical core subjects are listed on attachment, pages 2 and 3.

Together, the basic skills courses and the technical courses comprise the common core. This core ensures that the technician has the broad knowledge base and flexibility needed to function efficiently in high-technology occupations.

The chart on attachment, page 4, shows how this technical core can be used to support curricula for training technicians in other high-tech occupations. The specialty sequence of the curriculum would consist of five or six system-specific courses. These courses ensure that the technician would attain a certain level of expertise in a specialty area--robotics in this case.

The heart of the technical core is an intense laboratory-oriented curriculum in applied physics called Unified Technical Concepts (UTC) physics. UTC is a new approach to teaching physics. As the name implies, it teaches the same principles as they are applied in four various areas--mechanics, electricity, fluidics, and thermal. Some of the principles taught are force, resistance and power. Each is taught in a manner that shows its similarity in all areas. Another aspect of UTC is that its labs incorporate relevant, shop-type, equipment--not the typical, often impractical, lab equipment found in traditional physics labs.

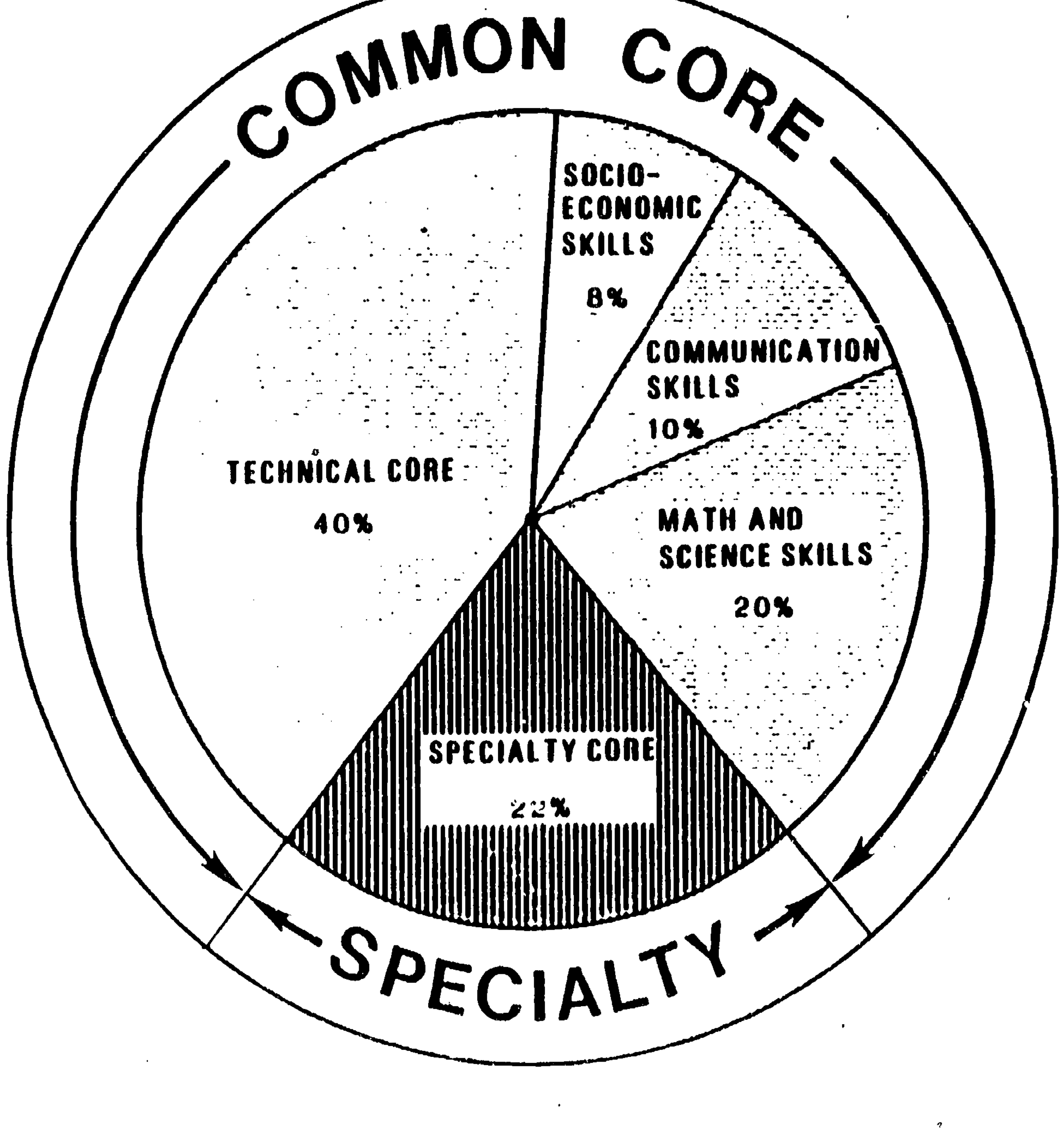
It is anticipated that five or six specialty courses will be added to the "core" to fulfill the requirements of RAST training. Based upon preliminary evaluation of the competencies, the new courses will be in computer control of machines and systems, programmable controllers, robot and system programming techniques, computer-integrated manufacturing, servosystems and feedback loops, and safety.

A preliminary model of the Robotics/Automated Systems Technology Curriculum, including the specialty courses is shown on attachment, page 5. Specific products of the national project are listed below, with dates of availability.

- Job Competency/Tasks required for Robotics/Automated Systems Technicians will be completed by March 30, 1984.
- A suggested two-year curriculum for Robotics/Automated Systems Technician Training will be prepared--the preliminary to be available by June 1, 1984, and the final by September 1, 1984.
- Module titles and outlines for all courses included in the curriculum--the preliminary to be available October 1, 1984, and the final December 1, 1984.

HIGH-TECHNOLOGY CURRICULUM STRUCTURE

DISTRIBUTION BY COURSES



ATTACHMENT

BRIEF DESCRIPTION OF TECHNICAL CORE

ELECTRICITY AND ELECTRONICS

Basic knowledge and skills in dc and ac electrical circuits to include circuit analysis, recognition and use of electrical components and electrical measurement instruments. Topics presented include voltage, resistance, current, power, Ohm's law, inductors, capacitors, series and parallel circuits, and magnetic circuits and devices.

ELECTRONIC DEVICES

Working knowledge of modern electronic devices and circuits in which they are employed. Electronic devices covered include PN diodes, Zener diodes, pnp and npn transistors, SCRs, unijunction transistors, JFETs, MOSFETs, and integrated circuits containing these devices. Devices used as digital switches, analog amplifiers and oscillators. Input and output devices; analog and digital systems.

CIRCUIT ANALYSIS (Replaces ELECTRONIC DEVICES in Computer and Microelectronics specialty Areas)

Equivalent circuits; loop and mode analysis; series/parallel circuits; resonance; filters; transients; time constants; pulse power circuits (pfn, Marks gen, etc.).

GRAPHICS

A beginning course in drawing/graphics. Includes lettering, line work, electrical symbols, mechanical symbols, blueprints, schematics, and shop drawings.

PROPERTIES OF MATERIALS

Comprehensive description of material properties under the separate classifications of physical, chemical, mechanical, thermal, electrical, magnetic, acoustical and optical properties. Typical properties studied include density, porosity, hygroscopicity, corrosiveness, composition, tension, compression, flexure, shear, impact, fatigue, elasticity, resilience, ductility, hardness, lubricity, brittleness, conductivity, heat capacity, permeability, and acoustic/optic transmissivity and reflectivity. Resource tables/handbooks identifed and used extensively.

MECHANICAL DEVICES AND SYSTEMS

Belt drives, chain drives, gear drives, drive trains, linkages, fans, blowers, valves. Covers operational procedures, use, maintenance, troubleshooting, repair and replacement.

HEATING AND COOLING

Radiation, convection, conduction and refrigeration; heat exchangers and heat balancing; temperature control and analysis of heat balance requirementes for typical industrial devices and systems.

FLUID POWER SYSTEMS

Overview of fluid power technology. Working knowledge of components in fluid power circuits. Hydraulic and pneumatic systems.Topics include fundamentals of fluid dynamics, fluid storage, conditioning and maintenance, pumps and compressors, actuators and fluid motors, fluid distribution and control devices, fluid circuits, and troubleshooting.

INSTRUMENTATION AND CONTROL

Practical knowledge and skills in specification, use and calibration of measuring devices. Principles and applications of automatic control processes. Topics include process control, pressure/level measurements, flow measurement, temperature measurement, mechanical measurement and pneumatic controls.

COMPUTER APPLICATIONS

Use of microprocessors and control devices for automated manufacturing, process control and data acquisition. Interfaces signals from measurement devices with computers; programs computer to analyze system condition from measured data and determined control device change required to optimize system operation; conditions output command signal from computer to automatically operated system control devices such as valves, pumps, boilers, etc.

MANUFACTURING PROCESSES

This course provides a background in manufacturing materials and manufacturing methods employed in cold working processes. Through lecture, demonstration, and practical applications the student becomes familiar with various types of machine tools, tooling, measuring, and inspection procedures. Automation and numerical control for machine tools are introduced.

INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT

This course deals with the source, distribution, and use of electrical power in industrial plants. The first part of the course describes ac electrical power as it arrives at the plant substation and the electrical equipment needed to transform it to useful voltages, distribute it effectively and protect it from overcurrent conditions. Equipment typically includes transformers, switchgear, fuses and relays. The second part of the course deals with electromechanical equipment required to convert electrical power into useful, rotational mechanical energy. Equipment typically includes ac and dc motors, motor controllers and synchromechanisms.

PROPOSED HIGH-TECHNOLOGY CURRICULUM IN AUTOMATED MANUFACTURING

APPLIED MATH AND SCIENCE

- ALGEBRA/TRIGONOMETRY
- ANALYTIC GEOMETRY

COMMUNICATIONS

- TECHNICAL COMMUNICATIONS
- COMPUTER BASICS

SOCIOECONOMIC

- ECONOMICS
- INDUSTRIAL RELATIONS

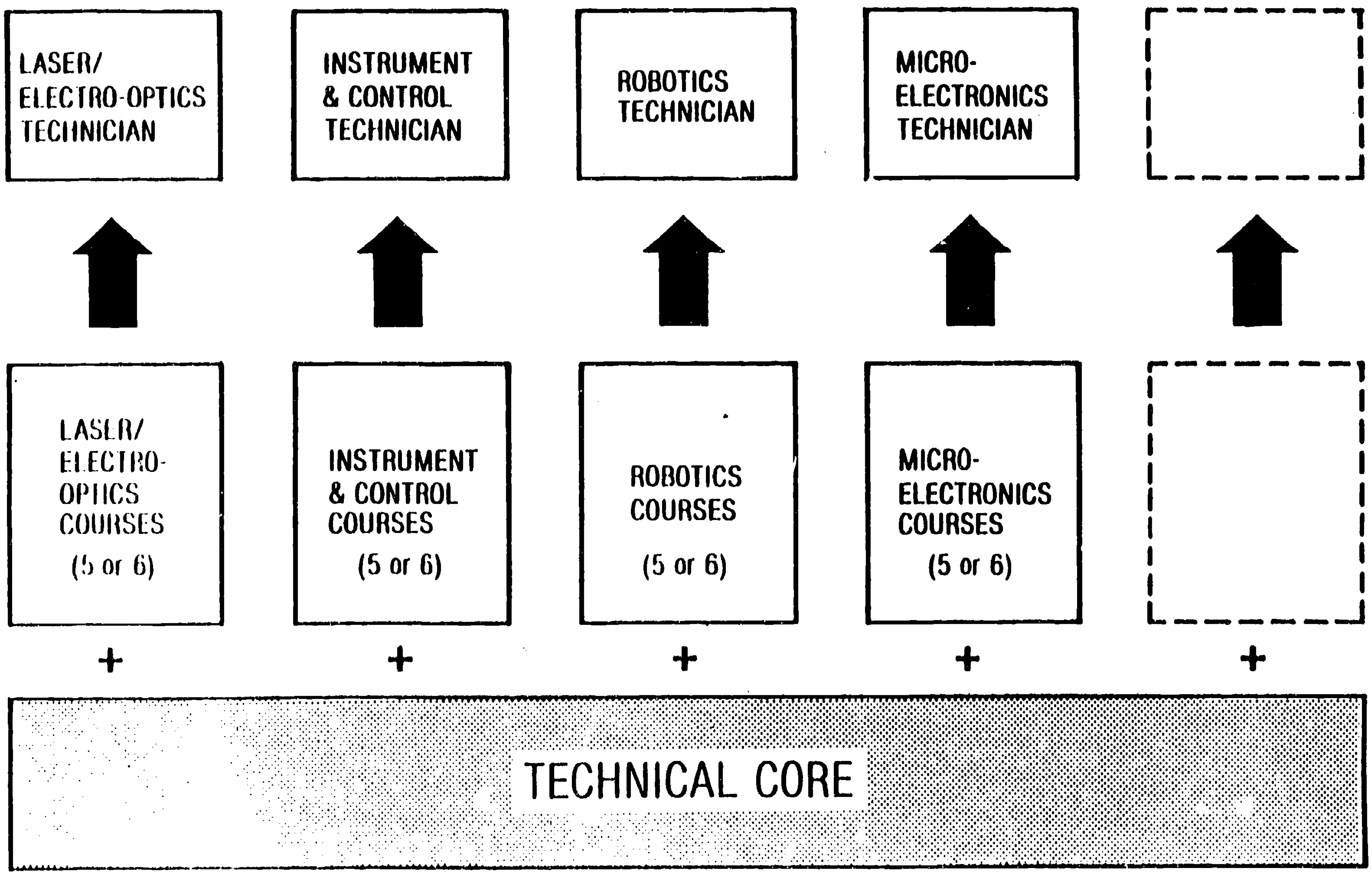
TECHNICAL CORE

- ELECTRICITY/ELECTRONICS
- GRAPHICS
- PROPERTIES OF MATERIALS
- MECHANICAL DEVICES
- MANUFACTURING PROCESSES
- ELECTRONIC DEVICES
- HEATING AND COOLING
- FLUID POWER
- INSTRUMENTATION AND CONTROL
- COMPUTER APPLICATOINS
- INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT

SPECIALTY

- MANUFACTURING TOOLS, FIXTURES AND MEASUREMENTS
- CAD/CAM SYSTEM HARDWARE AND FUNCTIONS
- CNC PROGRAMMING
- FUNDAMENTALS OF ROBOTICS
- AUTOMATED INTEGRATED MANUFACTURING SYSTEMS
- ELECTIVE

CORE CURRICULUM MODEL



TECHNICAL PAPER

MS84-560

Robotic/Automated Systems Technician Training in the USA— A State-of-the-Art Report

abstract

The Center for Occupational Research and Development and Robotics International of the Society of Manufacturing Engineers conducted a survey to determine the state of the art of robotics automated systems technician training. The results of this survey indicate that 56 postsecondary institutions currently provide robotics technician training. Additionally, there are 114 schools that offer robotics courses as electives. There are currently 159 instructors (76 with master's degrees and seven with Ph.D.s) teaching robotics, and 5,472 students studying to become robotics technicians in two-year associate degree and certificate programs. Very few of the programs evaluated provide broad-based interdisciplinary training for the students. There is a great need to upgrade the quality of robotic/automated systems technician training.

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conference

Robotic Education and Training: Meeting the Educational Challenge
August 20-22, 1984
Romulus, Michigan

index terms

Engineering Education
Education
Automation
Robots
Training

1984

Society of Manufacturing Engineers • One SME Drive • P.O. Box 930
Dearborn, Michigan 48121 • Phone (313) 271-1500

Robots are a key factor in the ability of the United States to maintain a competitive position in the world marketplace. Robots perform many tasks other than the classical hot, heavy and hazardous jobs. These other tasks include assembly (both large and small parts), parts sorting, palletizing, parts stacking (in an orderly manner), mail delivery and quality control.

While only approximately 4,000 robots currently are working in factories, it is estimated that by 1990, 50,000 robots will be installed and working.[1] Technicians competent in hydraulic, mechanical, electrical, thermal, and pneumatic systems, programmable controllers, sensing systems, safety, vision systems, and controller communications techniques and systems will be required to install, set up, calibrate, operate, service and maintain these robots and the automated systems where they are used.

Based on this study, there will be a need for 11,000 to 15,000 robotics technicians by 1990. To respond to this projected need, comprehensive, broad-based robotics technician training programs will have to be established to retrain existing workers and to educate and train new technicians.

The level of training required for robotics/automated systems technicians is considerably beyond that of a high school education. A high school student in a modern vo-tech program has insufficient time to adequately study the required high school subjects and also learn--during the same time frame--the material required to become a competent RAST. Therefore, the curriculum and supporting module outlines being developed focus on pre-baccalaureate, two-year "high-tech" robotics/automated systems programs. However, articulation into these programs from high school vocational programs is encouraged. Articulation is offering courses at the secondary level for which postsecondary credit will be offered. Facilities and/or faculty may be shared between educational institutions.

A project description and purpose follow:

The United States Department of Education awarded the Center for Occupational Research and Development (CORD) a contract to complete the following tasks:

(1) determine the current state of the art of robotics technician training;
(2) analyze tasks performed by robotics technicians;
(3) design a model curriculum for training robotics technicians; and
(4) develop complete module outlines for new courses in the curriculum.

CORD established an advisory committee whose membership represents robotics manufacturers and users, educators and organized labor. The panel provides input to and validates, by passing judgment on their value, the tasks required of robotics technicians.

The CORD staff compiled a list of tasks that was mailed to and reviewed by committee members. Their suggestions have been incorporated. The revised task list will establish requirements for robotics technician training. The committee will continue to review and comment on the curriculum and module outlines as these are being developed.

The state of the art (SOA), as used in this paper, is defined as the assessment of the current status of robotics and automated systems training programs that exist in public and private institutions throughout the United States. The State-of-the-Art Report answers the following questions:

(1) What training exists and where is it located?
(2) What is the extent of training at the different sites?
(3) What are the resources (instructors, etc.) available to students desiring robotics training?

[1] Smith, Donald N. and Wilson, Richard C. Industrial Robots - A Delphi Forecast of Markets and Technology. Society of Manufacturing Engineers, 1982.

To answer these questions, CORD assimilated data from Robotics International/Society of Manufacturing Engineers and from state vocational education directors. The standards of comparision are discussed below.

One of the first steps in developing a curriculum to train a technician is to define what is expected of that person during employment. A robotics/automated systems technician job description agreed upon by the Advisory Committee is as follows:

> Robotics/Automated Systems Technicians are technical specialists with broad-based electromechanical skills who are familiar with electronic, mechanical and hydraulic/pneumatic devices. They are usually specialists in computer-aided design, robotics, computer numerical control, or processing equipment, and they can set up automatic machines that work together as part of a total automated system. In their area of specialization, they can install, set up, troubleshoot, integrate, program, modify, test, operate and repair systems and components. They are field service, installation or service technicians. They will work either under the supervision of an engineer, as a member of a team or as a supervisor of other technicians.

In order to attain the required skills and knowledge, a technician will require a broad-based education that focuses upon the principles of several interrelated technologies. Therefore, the curriculum being developed will include fundamental courses from many disciplines: mechanics, electricity, hydraulics/pneumatics, heating and cooling, mathematics and computer literacy. At the conclusion of the two-year program, a graduate will understand the basic principles and their application to real devices. Most, if not all, of these fundamentals are interwoven in the principles of robotics and automated systems.

An effective technician will recognize systems that function as a unit. Student laboratories will include the assembly of individual components into functional systems. It is only by starting with, and understanding, components (building blocks) that the system operation is really understood. Laboratories, organized so that several systems work together, will allow the student to observe how robotics/automated systems work together in a typical manufacturing cell.

The student will become familiar with computers, how they function and how they can be made to work with each other. Most modern industrial processes have become highly automated. Repetitive tasks, such as machining, are accomplished by automated machines or industrial robots. These processes, machines and robots are controlled by computers. Technicians, working with automated equipment or data-management systems, will use both the software and hardware of computers and microprocessors. The development, installation, calibration, troubleshooting and repair of computerized equipment requires the combination of knowledge and skills found in computer programming and digital electronics.

A solid background in applied physics is fundamental to technician training. Applied physics should be taught during the entire first year, with at least half of the physics instruction being spent in laboratories observing and measuring physical phenomena on real-world equipment--and not just using sterile physics equipment. One of the courses, Unified Technical Concepts (UTC)*, includes the appropriate sequencing of applied physics, which is the broad technical base upon which the curriculum is developed. The various topics, or concepts, in UTC are presented in a unique manner, stressing the unification of basic physical concepts, such as force and resistance, across the traditional boundaries of mechanics, electricity, heat, and fluidics. Subsequently, device-oriented courses build upon the practical application of the physics principles presented in the UTC labs.

*Information about UTC Physics can be obtained from CORD, 601C Lake Air Drive, Waco, Texas 76710.

The sources and data collection agencies are discussed below.

A variety of institutions now offer robotics training. The state-of-the-art study examines major public and private sources of training including two-year technical schools or junior colleges which issue certificates or associate degrees. A few private schools provide full two-year robotics training. Programs other than two year, in both public and private sectors, offer robotics courses as electives supporting other major programs. Many institutions provide continuing education classes and/or seminars addressing the use of robots. These seminars are for familiarizing students with robots not for training technicians.

Some robot manufacturers provide training for their customers' personnel. Such vendor training may be on very different levels, ranging from training technicians and operators to training engineers in the use and programming of specific robots. Curriculum for vendor training, however, is directed at one or, at best, a few, specific model(s) of robot(s) produced by a particular manufacturer. Training does not include the fundamentals needed to make the technician versatile and able to work on a wide variety of robots and systems. In all likelihood, the technicians would not be able to work on and maintain more than one or two models of robots.

Manufacturers and users of robots often provide training for their employees. Like vendor training, user training is specific to the relatively few models in use at the local facility. Again, training would not include fundamentals and technical principles, and thus, would have a limited usefulness for the technician.

CORD worked cooperatively with outside organizations including Robotics International of the Society of Manufacturing Engineers (RI/SME) and the State Directors of Vocational Education in conducting this study. Through these organizations, public institutions were surveyed to obtain the data required.

In a summary of the data, Robotics International of the Society of Manufacturing Engineers survey requested that 3,200 institutions supply data describing their programs. Three hundred seventy-six replies were received in time to be evaluated. The analysis indicates that there are 56 two-year programs, with a total enrollment of 5,472 students. These institutions--that is, those most likely to provide comprehensive broad-based technician training--represent 11% of institutions surveyed.

Curricula offered by these institutions have various names, including Robotics Technician, Robotics/Automated Manufacturing, and Computer-Integrated Manufacturing. Curricula for these programs have been developed with one goal--training a person to be a technician who can install, operate, calibrate, troubleshoot and repair robots and automated production systems. Other data indicates that 114 schools offer programs with robotics/automated systems courses as options or electives in other specialty areas. Schools with elective robotics courses offer them as part of Electronics, Computers, Industrial Technology, Electromechanical Technology, and Industrial Electronics curricula. (This list is not all-inclusive.) Since those curricula have been developed to train students in areas other than robotics, it is logical to assume that the students will not receive the depth or breadth of exposure to robotics and automated systems required of robotics/automated systems technicians.

The institutions responding to the survey indicated that there are 159 instructors involved in classes where robots or robotics systems are studied. Of these, only seven have Ph.D. degrees while another 76 hold master's degrees. The remainder have B.S. or A.A.S. degrees, or experience with robots as their credentials. The number of instructors--159--does not include instructors of support courses or courses offered by other departments other than departments with robotics courses, as these persons support many areas of specialization--not just robotics.

The institutions contacted during the telephone follow-up indicated that quite often trade-offs of salary and benefits necessitate hiring instructors with less education/experience than is desirable. This means that the schools--to a large extent--do not have fixed minimum requirements for these instructors.

In conclusion, the survey was sent to 3,200 institutions; replies were received from 376 of these indicating 56 institutions have RAST programs in place, and 17 more are developing new programs. There may not be a need for more new programs. This fact is even more evident with the number of students currently enrolled--5,472--in RAST programs. Allowing for attrition and predictable delays in graduation beyond the scheduled two years, it is estimated that approximately 2,200 students will be graduating each year. The current projected enrollment levels at schools with existing and planned programs may be sufficient to meet the projected need of 11,000 to 15,000 technicians in this field by 1990.

Based upon the information supplied during the telephone follow-up to the survey, very few programs in place are competency-based, nor are many broad-based. The need, both immediate and future, will be for institutions to install broad-based programs or to increase the breadth of existing programs to include training on electrical, pneumatic and hydraulic robots and automated systems. Curriculum for RASTs must be based upon the mastery of technical principles, enabling students to learn the interrelationship of mechanical, electrical, thermal and fluidic fundamentals, and to learn new technologies as they emerge.

The model curriculum being developed will be available as a guide to help institutions establish new programs or improve existing programs. New course outlines will provide guidance as new modules are written in support of these new and/or improved programs.

Education for Robotics/Automated Systems Technicians

by

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Center for Occupational Research and Development
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Educational institutions across America are implementing curricula to train technicians to install, troubleshoot, repair, calibrate, operate and maintain robots and automated production equipment. These institutions are responding to the needs of industry representatives who predict a need for supertechs to meet current and future requirements. It is paramount that today's curricula provide training that will make the technician adaptable to new technologies as they develop.

At the same time, industries are modernizing their staffs to make better use of personnel. It is no longer justifiable to have an engineer--experienced in designing and creating--troubleshooting or maintaining production equipment; trained technicians are required for these tasks. Companies are finding it necessary, as their production facilities are modernized, to change the composition of the work force. As machines become more sophisticated and able to accomplish the critical work that has always required highly-skilled workers, the need for persons with these skills decreases. As requirements for skilled craft workers and assemblers decline, these persons will require retraining. This retraining may be provided through several vehicles. It may be company-sponsored, or through continuing education seminars. The training site may be a high school, college or technical school. Depending upon the ability and desire of the (displaced) worker, he or she may become a full or part-time student at a technical institution.

Before describing the training required of RASTs, it is proper to discuss their job description, which follows:

> Technicians are technical specialists with broad-based electromechanical skills who are familiar with electrical, electronic, mechanical and hydraulic devices. They are usually specialists in one or two identifiable types of specialty equipment. In their area of specialty, they can install, set up, troubleshoot, repair/replace parts, modify, test and operate the equipment. They may work either under the supervision of an engineer, as a member of a team, or as a supervisor of other technicians.

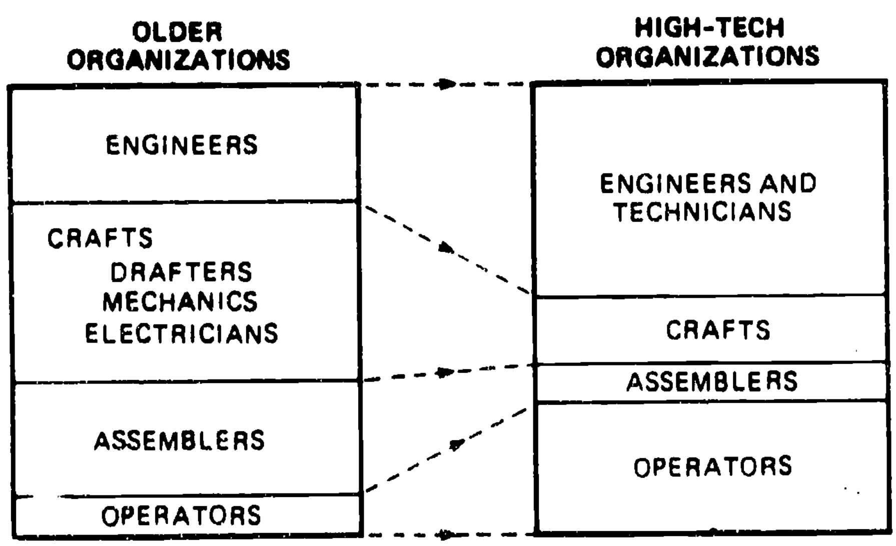

Fig. 1 Changes in the technical-skill mix required in modern manufacturing companies.

Past training produced workers who were predominantly skills-oriented. That is, trainees were taught "how to do" certain specific tasks. Courses were not knowledge-based. Trainees did not learn "why" certain things occurred or the correlation between similar characteristics, such as force and voltage, in various disciplines (mechanics and electricity). Consequently, when retraining was required, the trainee had to go through the whole skills program.

Tomorrow's technicians must have more than skills to be useful; they will need an understanding of how and why certain things work. Supertechnicians will need to know how several devices function in a system and understand the principles of mechanics, electricity, fluidics and heat transfer. Technicians must understand the interworkings of systems and how a change in one system will affect another related system. The training these future technicians receive should be broad-based--should cover mechanics, electricity, fluidics and heat transfer--and should be interdisciplinary--to show the similarities between the four systems.

The training curricula for technicians should be based upon practical, hands-on physics. This type of physics is often referred to as Unified Technical Concepts (UTC)*. It is a three-quarter (or two-semester) program wherein the student spends at least two hours in class and six hours in lab each week. The lab exercises expose the future technician to real-world equipment, the type to be found in industry--not the typical sterile equipment found in most college and university laboratories.

The first 80% of the curricula for high-tech technician training should be the same course, regardless of area of specialization. This percentage represents a core of knowledge that is common to all disciplines and includes the basics required in the learning paths of useful and functional technicians. A listing of the courses is given in Tables 1 and 2. This foundation facilitates retraining when retraining becomes necessary, since the subject areas form a core of basic factual knowledge that never changes.

TABLE 1. SUPPORT COURSES

Algebra
Trigonometry
Geometry
Physics
Technical Communications
Computer Basics
Socioeconomics

TABLE 2. TECHNICAL CORE

Electricity/Electronics
Electronic Devices
Manufacturing Processes
Graphics
Properties of Materials
Mechanical Devices
Industrial Electrical Power and Equipment
Fluid Power
Instrumentation and Controls
Computer Applications
Digital Electronics

After completing the core courses, the student can identify an area of specialty--for example Robotics/Automated Systems. This choice will specify the remaining 20% of the class work. Specialty courses are primarily applications of knowledge and systems-oriented. For example, see Table 3.

TABLE 3. SPECIALTY COURSES

Fundamentals of Robotics
Robot Tooling and Applications
Automated Systems Components
Automated Control Systems
Robotics/Automated Systems Applications and Maintenance
Robotics/Automated Systems Project

*For more information call CORD (1-800-231-3015).

In August 1983, the Center for Occupational Research and Development (CORD) received a contract from the United States Department of Education, Office of Adult and Vocational Education, to develop a model curriculum for Robotics/Automated Systems Technician Training. The three major tasks required by the contract are as follows: 1) to determine a current state-of-the-art of robotics/automated systems technician training in the U.S., 2) to write a report that defines the competencies required of robotics/automated systems technicians, and 3) to develop a model of curriculum and course outlines to support the curriculum for training robotics/automated systems technicians. Robotics International of the Society of Manufacturing Engineers surveyed 3,200 educational institutions to collect data for updating a directory of Robotics Education and Training Institutions; the same data were made available to CORD for use in determining the current state-of-the-art. Data collected included the type of program (Associate of Applied Science, certificate, etc.); number, education and experience of instructors; number of graduates; and current enrollment.

Fifty-six institutions offer two-year postsecondary robotics/automated systems technician training programs; however, only four or five of the programs are broad-based and interdisciplinary (or include intensive practical physics courses). In addition, there are 114 institutions that offer robotics, either as an option within a specialty area, or simply as an elective. These later programs are not broad; they expose the students to only a small portion of the information that is required for those who wish to become versatile employees.

Once the model curriculum is developed, schools wishing to either install a Robotics/Automated Systems Techncian program--or modernize an existing program--will be able to use this model curriculum as a guide. While it is a guide to the optimum program, local institutions will have to ensure that local needs are satisfied. In other words, the curriculum may have to be modified to satisfy specific local needs. For example, to make certain the curriculum satisfies the needs of local industries, the following steps should be taken:

Step One--Once the institution has given the program its own identity and assigned an individual to be responsible for implementation, that person should establish an advisory committee. This committee should be composed of ten to fifteen persons from local industry who are involved in the use of robots and automated manufacturing. Membership should include persons from management/engineering who are familiar with the work required to be done by technicians who install, setup, calibrate, troubleshoot, maintain and program this sophisticated automatic equipment. The purpose of this committee is to accomplish the following:

1) Verify the local need for this training.
2) Validate the competencies to be taught.
3) Ensure that the curriculum/courses being installed will train technicians who will be valuable to local industry.

Step Two--With the help and advice of the advisory committee, develop/define the job competencies (both terminal and enabling) required of a technician. A terminal competency is an observable, measurable task that a person is expected to perform; these tasks are most often small portions of larger jobs that must be performed. An enabling competency, which includes developing the supporting knowledge, is one that permits proper performance of terminal competencies.

Step Three--Compare course descriptions with the list of competencies. The competencies form the basis for designing new or modifying existing courses. Every course description should include a section that defines what competencies students are expected to learn or be able to perform. The local faculty will play an important role in this effort. Their input will help solidify their commitment to the new curricula.

Step Four--The curriculum must be evaluated for completeness, academic level, equipment used in experiments and learning exercises. While the advisory committee should help with this process, a specific evaluations committee should be formed. This committee should be charged with the responsibility of making the following determinations:

1) Determine the value of the program to the institutions.
2) Verify that students are employable locally.
3) Verify that the instructors have the required background.

Once the training program is in place, both the advisory committee and the evaluations committee should remain active. With both committees remaining active, the newly-instituted--or revised--training program can be updated continuously as new technologies develop.

APPENDIX C

Panel of Experts

1. Members
2. Agenda for October 19, 1983, Meeting
3. Minutes for October 19, 1983, Meeting
4. Agenda for March 16, 1984, Meeting
5. Minutes for March 16, 1984, Meeting
6. Agenda for November 6-7, 1984, Meeting
7. Minutes for November 6-7, 1984, Meeting

TASK ANALYSIS AND DESCRIPTIONS OF REQUIRED JOB COMPETENCIES OF ROBOTICS/AUTOMATED SYSTEMS TECHNICIANS

PANEL OF EXPERTS

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ROBOTICS TECHNOLOGY CURRICULUM ADVISORY COMMITTEE MEETING

AGENDA

October 19, 1983
8:00 AM

SME Headquarters
1 SME Drive, Dearborn, Michigan

8:00 Coffee and Rolls

8:30 Welcome, Introductions, and Announcements

8:45 Description of Robotics Technology Curriculum Project

9:00 Role of the Advisory Committee (Panel of Experts)
- Responsibilities
- Schedule of Meetings
- Other Participants

9:30 Determine Scope of the Project
- Definition of Robot
- Robotics, or Robotics/Automated Manufacturing
- Cooperative Effort with RI/SME

10:00 Break

10:15 Core Concept for Training Technicians in Advanced Technologies

11:00 Robotics Technician Job Description

11:30 Robotics Technician Task Analysis
- Review of Prior Work
- Project Approach to Task Analysis

12:00 Lunch

1:00 Review of Job Competencies

2:15 Current or Planned Robotics Technology Programs
- Institutions
- Other

2:45 Break

3:00 Review of Instructional Materials
- Plan to Develop Instructional Modules to Support Project Curriculum Model

3:30 Project Visibility Activities

3:45 Assignments

4:00 Date and Location of Next Meeting

Adjourn

MINUTES
ROBOTIC TECHNICIAN TASK ANALYSIS
PANEL OF EXPERTS MEETING

October 19, 1983

SME Headquarters
Dearborn, Michigan

The first Robotic Technican POE meeting was held on October 19, 1983, in Dearborn, Michigan. It was hosted by the Society of Manufacturing Engineers (SME) and chaired by Dan Hull, Project Director.

The agenda (attached) was presented to those members in attendance.

After introductions, the duties of the POE were described and a schedule of meetings was presented.

The concept proposed by CORD--that of using a broad-based curriculum common to several specialized technician programs--was described.

Following are the major accomplishments of the meeting:

- The requirements for technicians working with automated systems would be included. It was explained that robots must work with other equipment. Several robots or pieces of equipment working in consort constitute an automated system. The technician will need to be able to set up and cause two or more robots to work in consort.
- The definition of a Robotic Technician was expanded to Robotic/Automated Systems Technician.
- A list of competencies/task analyses which had been mailed to members previously was discussed. CORD is incorporating the comments made and will resubmit the list to the POE for validation.
- CORD presented a State-of-the-Art (SOA) determination format. POE members were requested to provide information appropriate to allow the SOA determination. Also, SME will help gather and compile similar information when their Robotics Directory is updated.
- POE members were requested to either participate on the project's behalf, or inform CORD when meetings/conferences were to be held, to inform persons interested in robotic technician training programs about the project and its progress.

The date and place of the next meeting was tentatively set for March 16, 1984, in Dallas, Texas. The exact location will be coordinated at a later date.

The meeting was adjourned at 3:30 p.m.

James E. Lovett
Research Associate

MEETING OF NATIONAL ADVISORY COMMITTEE FOR ROBOTICS/AUTOMATED SYSTEMS TECHNICIAN TRAINING

AGENDA

March 16, 1984

AMFAC Hotel West
Dallas/Fort Worth Airport, Texas

8:30 AM	Coffee and doughnuts
9:00	Welcome, Introductions
9:15	Current Project Status • State-of-the-Art Survey Results
9:30	Results of Competency Validation--Consensus
10:00	Relating the Validated Competencies to a Revised Core Curriculum • Design of Courses for Core Curriculum • Decision on Manufacturing Processes Course
12:00 Noon	Lunch--Catered
1:15 PM	Preliminary Design of Robotics/Automated Systems Specialty Courses Discussion on: • Course Content • Laboratory Design • Space Requirements • Equipment
2:40	Identify Reviewers of Instructional Module Outlines
3:00	Schedule of Remaining Project Tasks
3:15	Committee Recommendations
3:45	Assignments
4:00	Schedule Next Meeting
4:15	Adjourn

ROBOTICS/AUTOMATED SYSTEM TECHNICIAN TRAINING

Panel of Experts Meeting March 16, 1984

-MINUTES-

The second meeting of the Panel of Experts (POE) for the Robotics/ Automated Systems Technician Training curriculum project was held on March 16, 1984, at the AMFAC hotel at the DFW airport. The meeting agenda and a list of attendees are Attachment "A" to these minutes.

CORD Project Director Dan Hull opened the meeting at 9:00 A.M. After introductions of all members present, Mr. Paul Geib, Project Officer from the United States Department of Education, offered his welcome and appreciation of each member's participation.

The package of material that had been sent to each POE member was updated and then discussed. This package included (Attachment "B" to these minutes) the following:

Item 1	Validation Scores for Competencies
Item 2	Compilations of Validation Scores
Item 3	Plot of Cumulative Total Votes vs Score
Item 4	Core (CORD) Course Descriptions and Objectives
Item 5	Matrix Showing Core Course vs Competency
Item 6	List of Competencies for New (Specialty Courses)
Item 7	List of Competencies Deleted as a Result of Validation

As part of the discussion of these items, it was determined that:

- Item 1 - The competencies should be reworded using standardized terminology and phraseology.
- Item 1 - Competencies should be evaluated to determine which are terminal and which are enabling.
- Item 7 - The deleted competencies should be reviewed to determine which are "enabling"; these will then be added to a new section of the matrix titled "Enabling Competencies."

Upon completion of the above tasks, the revised material will be mailed to the POE members for review and comment.

The need for a "Manufacturing Processes" course was discussed. The competencies for this course had not been validated; however, several members had voiced the opinion that the course was needed. The POE agreed that this would be essential to provide the student an overview of the various manufacturing processes which may be automated or facilitated by the use of robots.

Six robotics/automated systems specialty courses were proposed. These courses provided "system competencies" which had not been previously validated. The ensuing discussion resulted in suggestions for courses to be redesigned to include more safety awareness, special tooling/applications, parts presentation problems, and sensor applications. It was also suggested that hard automation (not easily reprogrammed) be included in one of the specialty courses. CORD will redefine the specialty courses, identify appropriate competencies, and submit them to the POE for review and comment.

During the concluding comments, it was mentioned that there should be one course that includes extensive generic structured programming and that there should be more emphasis on digital electronics.

The meeting was adjourned at 3:00 P.M.

NATIONAL ADVISORY COMMITTEE FOR
ROBOTICS/AUTOMATED SYSTEMS TECHNICIAN TRAINING

AGENDA

FORD ROBOTICS/AUTOMATION APPLICATION CENTER
Dearborn, Michigan
November 6-7, 1984

November 6, 1984

8:30 - 8:45	Welcome, Introductions and Announcements
8:45 - 9:00	Status of Project
9:00 - 10:15	Review Curriculum and Specialty Courses
10:15 - 10:30	Break
10:30 - 12:00	Discuss Curriculum and Specialty Courses (Recommend Changes)
12:00 - 1:15	Lunch
1:15 - 2:30	Review new Module Outlines for Specialty Courses
2:30 - 3:00	Identification of Module Reviewers
3:00 - 3:15	Physics Module Outlines
3:15 - 3:30	Schedule of Deliverables for Completion of Project
3:30 - 3:50	Development of Course Materials
3:50 - 4:00	Wrap-Up

November 7, 1984

8:30 - 10:00	Description of FORD Robotics/Automation Application Center
10:00 - 12:00	Tour of Facility
12:00 - 1:00	Lunch
1:00	Adjourn

ROBOTICS/AUTOMATED SYSTEMS TECHNICIAN TRAINING
PANEL OF EXPERTS

Minutes of November 6, 1984 Meeting

The third meeting of the Panel of Experts (POE) for the Robotics/Automated Systems Technician Training curriculum project was held November 6, 1984, at Ford Motor Companies' Robotics and Automation Application Consulting Center in Dearborn, Michigan.

The Project Director, Mr. Dan Hull, opened the meeting at 8:30 AM with descriptive comments about the status of the project and a listing of contract deliverables in preparation.

The majority of the meeting time was spent performing a detailed review of the six specialty courses. This review included descriptions and outlines for each course in addition to the outlines of modules that support each of the specialty courses--they are listed below:

FR - Fundamentals of Robotics and Automated Systems

CA - Controllers for Automated Systems

AS - Automated Systems and Support Components

RI - Robotics/Automated Systems Interfacing

RS - Robotics/Automated Systems at Work

WC - Automated Work Cell Integration

All comments were recorded and incorporated. A copy of the modified course and module outlines is Attachment A.

The last order of business was the recommendation of module reviewers--persons who would voluntarily review the course and module outlines for completeness, appropriateness, and accuracy. The POE recommended the people listed on Attachment B.

The official POE meeting adjourned at 3:45 PM. All members were invited to return the following day to become acquainted with Ford's Consulting Center. All members returned and were treated to a very informative presentation by Ford personnel.

APPENDIX D

Robotics/Automated Systems Task Analysis Listing

ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING

	BASIC										TECHNICAL CORE												SPECIALTY					
	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	[illegible] FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS [illegible]	[illegible] AND PLACEMENT ROBOT/AUTOMATED SYSTEMS INTERFACE	ROBOT/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
A - Electrical/Electronic																												
Terminal Competencies																												
1. Use manufacturers' parts list and drawings concerning replacement parts for Robots/Automated Systems to																												
a. Identify part numbers							●						●															
b. Order replacement parts							●						●															
c. Install replacement parts							●						●															
2. Adjust, troubleshoot, repair, and/or replace:																												
a. Power supplies											●							●		●								
b. Servo amplifiers											●							●						●				
c. Motor control circuits											●							●		●				●	●			
d. Electronic sensors												●						●		●				●				
e. Transducers												●						●		●				●				
3. Attach and replace connectors to wire and fiber optic cables.											●							●		●								
4. I. .tall low & high voltage and interconnecting :gnal (wire and fiber optic) cables.											●							●										
5. Troubleshoot and repair wire and fiber optic system cable faults.											●							●										
6. Conduct routine preventive maintenance on electrical and electronic equipment in accordance with manufacturer's recommendations.											●									●								
7. Troubleshoot electronic failures to the circuit board level; replace defective circuit board.											●							●			●							

74

83

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

	BASIC										TECHNICAL CORE											SPECIALTY					
Task	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	AUTOMATED WORK CELL INTEGRATION
8. Conduct routine preventive maintenance on ac and dc motors in accordance with manufacturer's recommendations.																				●		●						
9. Install, adjust, troubleshoot and repair or replace to manufacturer's specifications:																												
a. Control devices																		●						●				
b. Relays (electromechanical and solid state)											●							●		●		●						
c. Sensors																		●						●				
d. Limit switches																		●				●		●	●			
e. Transducers																		●						●	●			
f. 1 Φ and 3 Φ electrical equipment											●									●		●			●			
10. Connect fiber-optic cables to electronic equipment.											●							●										
11. Troubleshoot, repair or replace fiber optic components/systems.																		●						●	●	●		
12. Program stepper motors.																				●		●		●	●			
13. Apply bridge circuits to measuring voltages and currents.											●							●										
14. Replace components on circuit boards.												●							●									
15. Solder and desolder electrical connections.											●	●						●	●	●								
16. Install and remove circular (multipin), coaxial, and in-line plugs and receptacles.											●								●									
17. Measure and set voltages and currents.																												
a. Facility power																				●								
b. Equipment power supply												●													●			

ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

A - Electrical/Electronic

Enabling Competencies

	BASIC										TECHNICAL CORE												SPECIALTY						
	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] AT WORK	AUTOMATED WORK CELL INTEGRATION
1. Read schematic diagrams.							●				●									●									
2. Read wiring diagrams.							●				●									●									
3. Interpret industrial electrical symbols and line diagrams from printed material and/or graphic display systems.											●									●									
4. Describe in writing how switches and solenoids work.							●				●									●		●							
5. De[illegible]ibe in writing SCR controls.							●					●						●											
6. Analyze series and parallel circuits.											●																		
7. Use operational amplifiers as followers, inverters, summers, integrators, and differentiators.												●						●											
8. Use an oscilloscope to determine wave forms.					●			●			●																		
9. Determine signal frequency.											●							●											
10. Describe ac and dc current flow.				●							●																		
11. Describe lead acid battery construction.											●																		
12. Describe ac and dc electric motor operation.				●							●									●		●							

8·

80

ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

B - Pneumatic

	BASIC: Algebra	Trigonometry	Geometry/Calc	UTC Physics I	UTC Physics II	UTC Physics III	Technical Communications	Computer Basics	Economics in Tech.	Industrial Relations	TECHNICAL CORE: Fundamentals of Electricity & Electronics	Analog Circuits and Active Devices	Graphics	Manufacturing Processes	Properties of Materials	Mechanical Devices and Systems	Fluid Power	Instrumentation & Controls	Computer Applications	Industrial Electrical Power and Equipment	Digital Electronics	Electromechanical Devices	SPECIALTY: [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Automated Work Cell Integration
Terminal Competencies																												
1. Maintain pressure regulators.																	●											
2. Install, adjust troubleshoot and repair or replace pneumatic:																												
a. Airlines																	●											
b. Pumps																	●											
c. Gages																	●											
d. Filters																	●											
e. Control valves																	●											
f. Actuators																	●											
g. Cylinders																	●											
h. Pressure switches																	●											
i. Positioner relays																	●											
3. Adjust a pneumatic-sensor temperature controller to a specified mixed air temperature.																	●											
4. Properly use dampers, thermostats, switches, pneumatic positioners, linkage assemblies and accessories in pneumatic systems.																	●											
5. Conduct routine preventive maintenance on pneumatic equipment in accordance with manufacturer's instructions.																	●											
Enabling Competencies																												
1. Sketch flow path symbols and air logic drawings.																	●											
2. Interpret flow path symbols and air logic drawings.																	●											
3. Identify and use proper size of pneumatic piping.																	●											

Prepared by the Center for Occupational Research and Development, Waco, Texas.

ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

C - Hydraulic

	BASIC										TECHNICAL CORE												SPECIALTY					
	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	AUTOMATED WORK CELL INTEGRATION
Terminal Competencies																												
1. Install, adjust, troubleshoot, and repair or replace hydraulic:																												
a. Lines																	●											
b. Pumps																	●											
c. Gages																	●											
d. Filters																	●											
e. Accumulators																	●											
f. Volume controls																	●											
g. Servo valves																	●	●		●				●		●	●	●
h. Directional control valves																	●									●	●	●
i. Pressure control valves																	●									●	●	●
2. Test for hydraulic oil quality and use external filter system to purify.																	●											
3. Control oil pressure and temperatures.																	●											
4. Null hydraulic servo systems.																	●											
5. Calculate hydraulic system pressure losses.																	●											
6. Conduct routine preventive maintenance on hydraulic equipment in accordance with manufacturer's specifications.																	●											
Enabling Competencies																												
1. Identify and use proper-size lines.																	●									●		
2. Describe the relationship between hydraulic pressure and flow.																	●											

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

BASIC — TECHNICAL CORE — SPECIALTY

D - Mechanical	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	PRINCIPLES OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOT/AUTOMATED SYSTEMS INTERFACES	ROBOTS/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
Terminal Competencies																												
1. Set and adjust mechanical stops.																●												
2. Set actuators to proper end positions.																●												
3. Install and maintain linkage.																●												
4. Install and maintain gear trains.																●												
5. Conduct routine preventive maintenance on mechanical equipment in accordance with manufacturer's specifications.																●												
Enabling Competencies																												
1. Identify elements used in selection and design of processes that can be automated.																												
a. Welding															●													
b. Painting															●													
c. Material handling															●													
2. Determine speed and torque ratios.																●												

Prepared by the Center for Occupational Research and Development, Waco, Texas.

ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

E - Computer

Terminal Competencies

BASIC — TECHNICAL CORE — SPECIALTY

Task	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUNDAMENTALS OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOTIC/AUTOMATED SYSTEMS INTERFACING	ROBOTIC/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
1. Troubleshoot malfunctions in computer system to circuit board level.																			●					●	●			
2. Install, troubleshoot, remove and replace:																												
a. Memory devices																			●									
b. Displays																			●									
c. Control circuits																			●									
d. Keyboards and printers																			●									
e. Central processing unit (CPU)																			●									
f. Interface modules																			●									
3. Install input/output (I/O) devices in accordance with manufacturer's specifications:																												
a. Cathode-ray tubes (CRTs)								●											●									
b. Printers								●											●									
c. Tape drives																			●									
d. Disk drives								●											●									
e. Plotters																			●									
f. Flat screen displays (including gas plasma displays)																			●									
4. Install module or board-mounted RAM and ROM memory devices in accordance with manufacturer's specifications.																			●									
5. Load and run diagnostic routines.								●											●									
6. Interpret diagnostic printouts.								●											●									
7. Install programmable controllers.																								●	●	●		
8. Use diagnostic routine program language written in machine language(s).								●											●					●				

ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

BASIC — TECHNICAL CORE — SPECIALTY

Task	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOTICS/AUTOMATED SYSTEMS INTERFACES	ROBOTICS/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
9. Program and/or reprogram PCs (drum, relay, and microprocessor types) for specific sequence of events in performing an application.																								●				
a. Prepare a flow chart for a specific sequence of events in performing given application.																								●				
b. Enter instructions into control unit.																								●				
c. Run program to see if control unit executes properly.																								●				
d. Edit or debug program as necessary.																								●				
e. Download and upload system.																								●				
f. Recognize and resolve hardware/software impedance matching problems.																								●				
10. Write, enter, and debug programs in one structured language.								●											●									
11. Install, set up, calibrate, troubleshoot and repair or replace data transmissions systems.																			●									
Enabling competencies																												
1. Characterize digital circuits.								●													●							
2. Describe microprocessor input/output characteristics.								●											●									

9?

ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

BASIC — TECHNICAL CORE — SPECIALTY

F - Electromechanical

Terminal Competencies

1. Install, adjust, troubleshoot and repair or replace:
2. Install, adjust, troubleshoot and repair or replace sensors for:

Enabling Competency

1. Describe the applications of the following systems to a robotic work cell:

	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOTICS/AUTOMATED SYSTEMS INTERFACES	ROBOTICS/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
Terminal 1. a. Servo motors																		●				●						
b. AC pump motors (vacuum and pressure)																				●		●						
c. Speed-reduction units																●						●						
d. Clutches																●												
e. Stepping motors																				●		●		●				
f. Mechanical drives for feedback system																●				●								
Terminal 2. a. Flow control																●		●		●		●						
b. Liquid-level control																●		●		●		●		●				
c. Ultrasonic control																		●		●				●	●			
d. Optoelectric															●			●						●	●	●	●	
e. Tactile															●	●		●				●		●	●			
f. Video															●	●		●						●	●			
Enabling 1. a. Hydraulic/electrical/pneumatic positioners and sensors																	●	●						●	●			
b. Motor drives and servos											●							●				●		●	●			
c. Control systems including feedback																●		●				●		●				
d. Mechanical linkages/gears																●				●								
e. Electrical power system											●									●		●						

ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

G. General

Terminal Competencies

	BASIC										TECHNICAL CORE												SPECIALTY						
	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOTICS/AUTOMATED SYSTEMS INTERFACE	ROBOTICS/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION	
1. Effectively select and utilize such test equipment as time-domain reflectometers, oscilloscopes, spectrum analyzers, function generators, chart recorders, and multimeters for troubleshooting and repair of electronic circuits.											●	●								●	●			●					
2. Identify and demonstrate proper operation, care and maintenance of hand power tools.														●		●											●	●	
3. Select and install the proper fastener for a given job.																●													
4. Identify and use appropriate lubricant.																●	●												
5. Use manual's troubleshooting charts to aid fault isolation/repair.																								●	●	●	●	●	●
6. Maintain work log sheets.							●			●																			
7. Draw logic diagrams.																			●		●			●					
8. Read, understand and comply with requirements of service bulletins.							●						●																
9. Convert measurements between English and SI systems.													●																
10. Use both inside and outside micrometers.														●		●													
11. Use manufacturer's manuals as a guide to troubleshoot, repair, test and operate a failed machine.							●				●					●										●	●	●	
12. Use manufacturer's manuals to determine a machine's normal operating characteristics.							●				●					●										●	●	●	
13. Using a manual, identify operational/functional systems.							●				●					●										●	●	●	

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

BASIC — TECHNICAL CORE — SPECIALTY

G. General — Enabling Competencies	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUNDS. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOTICS/AUTOMATED SYSTEMS INTERFACES	ROBOTICS/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
1. Recognize a mechanical problem which may, at first examination, appear to be an electrical one and vice versa.																				●						●	●	●
2. Exhibit proper working habits (attitude and safety).										●																●	●	●
3. Interpret drawings of parts.							●						●															
4. Interpret graphs and charts.							●						●															
5. Read and use acceptable twelfth-grade English.							●																					
6. Perform trigonometric calculations.		●																										
7. Explain the difference between accuracy, precision, and repeatability.							●						●															
8. Explain the difference between direct and indirect measurements.													●	●														
9. Communicate																												
a. Orally							●																					
b. Listening							●																					
c. Reading							●																					
d. Write technical reports							●																					
e. Graphically							●						●															

ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

BASIC / TECHNICAL CORE / SPECIALTY

H - Factory Processes Enabling Competencies	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOTICS/AUTOMATED SYSTEMS INTERFACES	ROBOTICS/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
1. Describe the following operations performed on a lathe:																												
a. Plane or straight turning														●														
b. Facing														●														
c. Parting														●														
d. Chamfering														●														
2. List common lathe accessories and attachments.														●														
3. Identify important features of a horizontal turret lathe.														●														
4. Describe a screw machine and the types of jobs accomplished on it.														●														
5. Define an electron beam and how it is used as a special cutting tool.														●														
6. Identify the machines and tools used for:																												
a. Stamping														●														
b. Piercing														●														
c. Bending														●														
d. Drawing														●														
e. Rolling														●														
7. Describe/list the cutting tools normally used on:																												
a. Mills														●														
b. Lathes														●														
c. Drill presses														●														
8. Describe painting processes.														●														

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

Task	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOTICS/AUTOMATED SYSTEMS INTERFACES	ROBOTICS/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
	BASIC										TECHNICAL CORE												SPECIALTY					
9. Define and give an example of the following measurement terms:																												
a. Tolerance													●	●														
b. Allowance													●	●														
c. Clearance													●	●														
d. Basic size													●	●														
e. Standard size													●	●														
f. Nominal size													●	●														
10. Describe the differences between MIG, TIG and stick arc welders.														●														
11. Describe gas welding equipment.														●														
12. Explain flow and dip coating.														●														
13. Describe anodizing.														●														
14. Describe electroplating equipment and explain the process.														●														
15. Describe aerobic and anaerobic adhesives.														●														
16. Explain the difference between thermoset and thermoplastic plastics.														●														
17. Describe injection molding.														●														
18. Describe vacuum forming.														●														
19. Compare similarities and differences of ECM and EDM.														●														
20. List important factors that control the quality of surface finish obtained by ultrasonic machining.														●														

ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROL LINES FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOTICS/AUTOMATED SYSTEMS INTERFACES	ROBOTICS/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
	BASIC										TECHNICAL CORE												SPECIALTY					
I - Automated Systems																												
Terminal Competencies																												
1. Measure robot performance (distance, positioning, accuracy, and repeatability).																							●					
2. Use teaching pendant for testing, editing, and setup.																							●	●				
3. Disassemble, repair, test and return to service robots which have failed.																										●	●	●
4. Install, adjust, troubleshoot, repair or replace:																												
a. Industrial robots.																										●	●	●
b. End effectors																										●	●	●
c. Smart actuators																										●	●	●
5. Coordinate the operation of several pieces of automatic equipment.																											●	●
6. Adjust feedback loops that include:																												
a. Encoders/decoders																		●				●		●				
b. Optical sensors																		●						●				
c. Electronic sensors																		●				●		●				
d. Microprocessor																		●	●					●				
e. Count stepper-motor pulses																		●						●				
f. Optoelectronics																		●						●				
g. Hall-effect devices																		●						●				
h. Velocity sensors																		●						●				
i. Position detectors																		●				●		●				
7. Interconnect robots and other equipment.																										●	●	●
8. Adjust machines for accuracy and repeatability.																										●	●	●
9. Set up machine vision systems.																									●	●	●	●
10. Match off-the-shelf end effectors to the requirements of various manufacturing operations.																							●			●	●	●
11. Analyze robot task requirements of a manufacturing operation.														●												●	●	●

Prepared by the Center for Occupational Research and Development, Waco, Texas.

ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

BASIC — TECHNICAL CORE — SPECIALTY

Task	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOTICS/AUTOMATED SYSTEMS INTERFACES	ROBOTICS/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
12. Analyze and select appropriate robot sensing requirements for certain manufacturing operations.														●										●		●	●	●
13. Start-up and debug a robot system.																										●	●	●
14. Start-up and shut down an automated production systems.																									●			●
15. Specify safety considerations for personnel, work area, operations, and maintenance.							●			●																●	●	●
16. Test wiring of each subassembly of a robot; test the overall, connected wiring of the total robot.																										●	●	●
17. Install a programmable controller and its input/output devices.																		●		●				●		●	●	●
18. Follow troubleshooting procedures recommended by the manufacturer to diagnose, isolate, and repair a robot/automated system.																										●	●	●
19. Analyze operating difficulties of installed robots; perform necessary corrective adjustments to return system to normal operation.																										●	●	●
20. Perform field testing of a robot and check to assure that its performance is in accordance with specifications.																										●	●	●
21. Perform electrical adjustments on servo power amplifiers.																		●		●				●	●			
22. Perform zeroing of encoders.																		●						●		●	●	●
23. Specify the robot coordinate system.																										●	●	●
24. Develop material handling specifications for a work cell.																												●
25. Specify the robot-to-material interfaces.																										●	●	●
26. Define the human interface with a robot.																										●		
27. Define axis control and feedback specifications.																										●	●	●
28. Set up, program, troubleshoot a system comprised of a minimum of two transfer lines, one robot, and at least one machining center.																											●	●

ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

	BASIC										TECHNICAL CORE												SPECIALTY					
Task	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOTICS/AUTOMATED SYSTEMS INTERFACES	ROBOTICS/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
29. Set up, etc., robot to either remove parts from transfer line and palletize them or to depalletize parts and place them on a transfer line.																										●	●	●
30. Given the above setups, the instructor will install a programming error. The student (team) will diagnose and correct the problem and te't the solution.																												
a. Programming																								●	●	●	●	●
b. Mechanical stops																								●	●	●	●	●
c. Electrical																								●	●	●	●	●
d. Hydraulic power supply																										●	●	●
31. Set up a robot to either paint parts on a moving line or weld parts on a moving line (line will stop for welding cycle).																											●	●
32. Set up, etc., a robot to assemble two parts--use at least three fasteners:																												
a. Index																									●		●	●
b. RCC																									●		●	●
c. Pick up																									●		●	●
d. Fasteners																									●			
e. Install parts																									●			
33. Configure a system for counting regular/irregular shaped objects moving on an overhead track.																											●	●
34. Define signal-sensing-control and power interfaces involved in the first two problems.																										●	●	●
35. Operate the following equipment																												
a. End effectors																							●		●	●	●	●
b. Grippers																							●		●	●	●	●
c. Magnetic pickups																							●		●	●	●	●
d. Vacuum pickups																							●		●	●	●	●
e. Compliance devices																							●		●	●	●	●

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ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

	BASIC										TECHNICAL CORE												SPECIALTY					
	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOTICS/AUTOMATED SYSTEMS INTERFACES	ROBOTICS/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
36. Adapt the following to robotic application:																												
a. Welder																										●	●	●
b. Adhesive applicators																										●	●	●
c. Paint sprayers																										●	●	●
d. Grinders																										●	●	●
37. Adapt the following to work with automated systems:																												
a. Conveyors																									●	●	●	●
b. Bulk feeders																									●	●	●	●
38. Set up, operate, troubleshoot, and repair automated:																												
a. Warehousing systems																											●	●
b. Machinery operations																											●	●
c. Coating/application systems																											●	●
d. Assembling stations																											●	●
e. Material handling systems																											●	●
39. Program a host computer to control several "lower-level" computers that in turn control portions of an automated system.																									●		●	●
Enabling Competencies																												
1. Identify major systems of a robot.																							●					
2. Describe robot drive system operation.																							●					
3. Describe operation of various types of industrial robots.																							●					
4. Describe mobility of an industrial robot.																							●					
5. Describe transmission operation.																												
a. Gears																●							●					
b. Pulleys, belts																●							●					
c. Bearings																●							●					

ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

BASIC **TECHNICAL CORE** **SPECIALTY**

Task	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	BASIC OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOTICS/AUTOMATED SYSTEMS INTERFACES	ROBOTICS/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
6. Identify a robot's work envelope.																							●					
7. Be conversant in robot terminology.							●																●					
8. Demonstrate knowledge of safety requirements for working around robots.																							●			●	●	●

Prepared by the Center for Occupational Research and Development, Waco, Texas.

ROBOTICS/AUTOMATED SYSTEMS TASK ANALYSIS LISTING (Continued)

BASIC | TECHNICAL CORE | SPECIALTY

J - Design	ALGEBRA	TRIGONOMETRY	GEOMETRY/CALC	UTC PHYSICS I	UTC PHYSICS II	UTC PHYSICS III	TECHNICAL COMMUNICATIONS	COMPUTER BASICS	ECONOMICS IN TECH.	INDUSTRIAL RELATIONS	FUNDAMENTALS OF ELECTRICITY & ELECTRONICS	ANALOG CIRCUITS AND ACTIVE DEVICES	GRAPHICS	MANUFACTURING PROCESSES	PROPERTIES OF MATERIALS	MECHANICAL DEVICES AND SYSTEMS	FLUID POWER	INSTRUMENTATION & CONTROLS	COMPUTER APPLICATIONS	INDUSTRIAL ELECTRICAL POWER AND EQUIPMENT	DIGITAL ELECTRONICS	ELECTROMECHANICAL DEVICES	FUND. OF ROBOTICS AND AUTOMATED SYSTEMS	CONTROLLERS FOR ROBOTS AND AUTOMATED SYSTEMS	AUTOMATED SYSTEMS AND SUPPORT COMPONENTS	ROBOTICS/AUTOMATED SYSTEMS INTERFACES	ROBOTICS/AUTOMATED SYSTEMS AT WORK	AUTOMATED WORK CELL INTEGRATION
Terminal Competencies																												
1. Create two-dimensional drawings using the graphics terminal, digitizer, and plotter as design and drafting tool.													●															
2. Sketch views not shown on a drawing.													●															
Enabling Competencies																												
1. Explain the hazard of accumulated tolerances (on a drawing).							●						●	●														
2. Determine critical dimensions.													●	●														
3. Describe the meaning of dimensions/tolerances shown on drawings.													●	●														
4. Identify the components of a computer-aided drafting system.													●	●					●									
5. Determine interrelationships of working dimensions.													●	●														
6. Determine critical dimensions.													●	●														

APPENDIX E

Core Curriculum Explanation

121

PREPARING ENGINEERING TECHNICIANS IN HIGH-TECHNOLOGY JOBS

Daniel M. Hull, President
Center for Occupational Research and Development

In the past several years, rapid advances in the applications of science and digital computers have brought about a technical revolution that has significantly altered the way we live and work in our homes, offices and plants. Moreover, these advances have drastically changed the equipment and methods for receiving, storing, manipulating and sending information. These marked technological breakthroughs--this revolution--is frequently called high technology.

High technology has undeniably altered our workforce requirements for new and better-trained technical workers and operators of high-tech equipment. Communities that seek to attract and maintain high-tech industries depend directly on public educational institutions to provide an adequate supply of advanced-level technical workers--scientists, engineers and technicians. But, beyond meeting the critical numbers of technical workers needed by industry, educational institutions must be especially attentive to the quality and content of the curriculum that is used to educate the technical workforce. This report will address the format, content and level of education and training for engineering technicians.

CHARACTERISTICS OF HIGH TECHNOLOGY

Four characteristics of high technology are significant in the education of engineering technicians: (1) broad knowledge base, (2) heavy computer use, (3) rapidly changing technologies, and (4) systems-oriented emphasis.

BROAD KNOWLEDGE BASE--Today's technicians in modern industries need to know far more than that required to complete the obvious tasks and procedures associated with their jobs. Employees recognize that the complexity of today's equipment extends well beyond the simple, fail-safe devices of yesterday. Consequently, the trend in education today must be to prepare technicians who understand the entire system with which they work and the technical principles that govern the behavior of each device. Furthermore, technicians must realize that, in changing one parameter in a large system, the entire system may be altered or affected as a consequence.

At this point it is useful to distinguish between the occupations of technicians and operators. A technician builds, installs, modifies, maintains and repairs modern equipment, whereas an operator controls the function of the equipment. Technicians work "inside" high-tech equipment, and operators work "outside" the equipment. The scientific knowledge base of the technician must be much greater than that of an operator.

In most instances, the role of the technician falls between that of the vocational industrial craftsman and the professional engineer. This is a broad range and is ill-defined in practice, having gray areas at either end of the continuum and at many points in between. Perhaps the best way to characterize a technician is by a summary of the tasks performed and accompanying skills required. Thus a technician is one who:

1. Performs tests on mechanical, hydraulic, pneumatic, electrical, or thermal components or systems; prepares appropriate technical reports covering the tests.

2. Obtains, selects, compiles, and uses technical information from precise measuring and recording instruments.

3. Analyzes and interprets information obtained from precise measuring and recording instruments and special procedures and techniques.

4. Prepares or interprets engineering drawings and sketches; writes detailed specifications or procedures for work.

5. Designs, helps develop, or modifies products, techniques, and applications in industrial settings.

6. Plans, supervises, or assists in the installation and inspection of complex scientific apparatus, equipment, and control systems.

7. Operates, maintains, and repairs complex apparatus and equipment with extensive control systems.

8. Advises, plans, and estimates costs as a field representative of a manufacturer or distributor of technical apparatus, equipment, services, and/or products.

9. Applies knowledge of science and mathematics while providing direct technical assistance to physical scientists or engineers engaged in scientific research and experimentation.

HEAVY COMPUTER USE--Many modern industrial processes have become highly automated. Repetitive tasks in machining, assembly, painting and testing are accomplished by automated machines or industrial robots. These processes, machines, and robots are controlled by sophisticated computers. Other high-technology occupations require rapid access to enormous banks of information and the ability to assimilate and analyze data in "real time." Technicians working with automated equipment or data-management systems must be able to use both the software and hardware of computers and microprocessors. The development, installation, calibration, troubleshooting, and repair of most computerized equipment require the combination of knowledge and skills found in computer programming and digital electronics.

RAPIDLY CHANGING TECHNOLOGIES--In the past thirty years, the evolution of science and technology has been characterized by rapid growth and advancement. Recent advances in telecommunications and breakthroughs in microelectronic chips have enabled scientists, engineers, and technologists to have access to vast amounts of information and to their own powerful personal computers. This new era in data availability and computational capability guarantees that our technologies will continue to grow and change at unprecedented rates; and, indeed, the need for our country to remain competitive in the international marketplace requires that our technologies advance.

In fields such as laser/electro-optics and telecommunications, approximately fifty percent of a technical specialty changes every three or four years. Therefore, educators must prepare technical workers with a broad technical and mathematical base. Only then can they continue to learn new techniques and assimilate new information after they are employed.

SYSTEMS-ORIENTED EMPHASIS--A careful examination of scientific hardware and modern industrial processes reveals complex systems that are composed of electrical, electronic, mechanical, pneumatic, hydraulic, thermal, and optical devices. The technician who works with high-technology equipment and systems must have a broad technical background to deal with such diverse systems. Specialists in electronics, mechanics, fluids or optics are still required, but the greatest need is for the "supertech" who can install, operate, maintain and repair systems that incorporate combinations of electrical motors, digital circuits, mechanisms, hydraulic actuators, lenses, light sources, and transducers. Many of these systems are controlled by microcomputers and require heating and cooling systems for proper operating temperatures.

CURRICULA FOR HIGH TECHNOLOGIES

CORD has designed and developed a Core Curriculum concept and models for engineering technicians that are implemented in postsecondary associate degree programs throughout the country. The goal of this curriculum approach is to prepare technicians with the following characteristics:

Systems oriented

Combination of skills--interdisciplinary
- Electrical
- Mechanical
- Fluid
- Thermal
- Optical
- Microcomputers

Strong technical base
- Capable of learning new specialties as the technology changes

A curriculum designed to meet these needs ought to be made up of two main parts--a common core and a specialty sequence (see Figure 1). The common core, by far the largest part, would contain basic units in mathematics and the physical sciences; several required units in human relations and effective communication; and a technical core of units from the various areas that govern high-tech occupations. The second part of the curriculum, the specialty sequence, would ensure that the student attained a certain level of expertise in a particular choice of high-tech specialization.

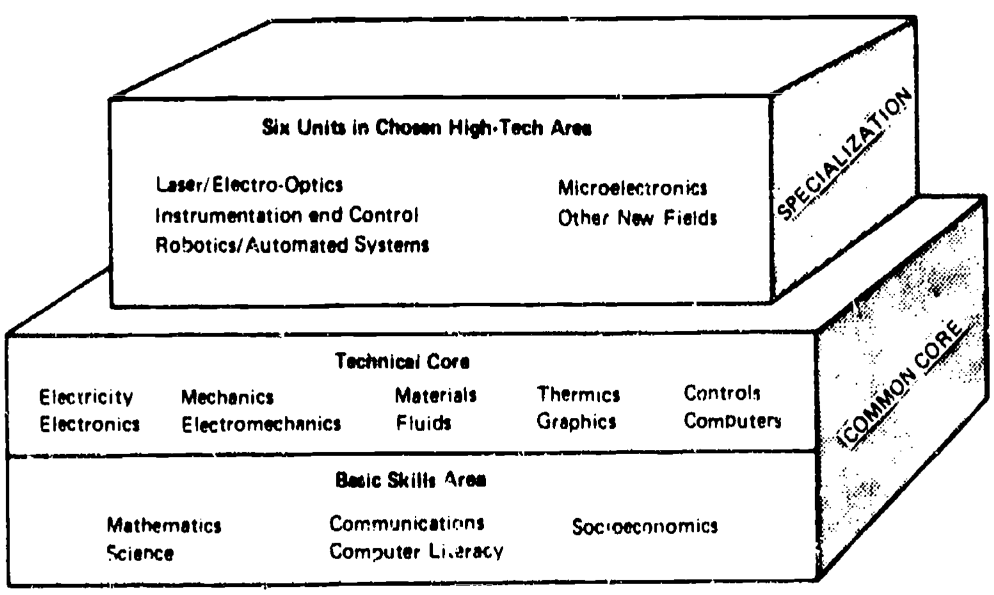

Figure 1. High-technology curriculum structure.

Schools, implementing this curriculum approach, provide a core of courses that all technicians take and 5-6 specialty courses to prepare a technician in a particular field of specialization. This is shown graphically in Figure 2.

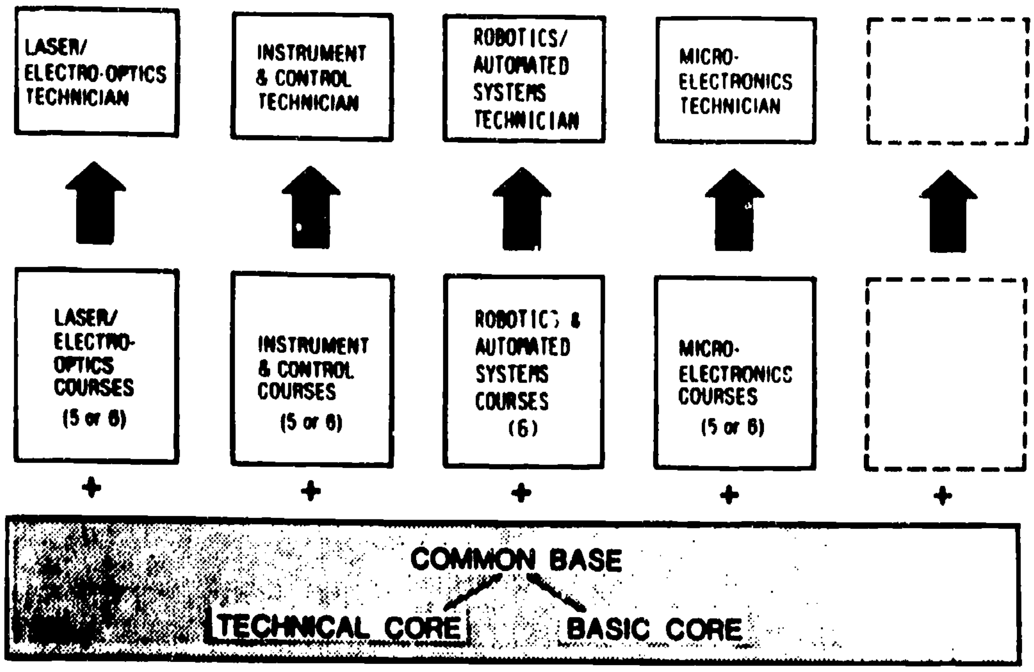

Figure 2. Postsecondary-level high-technology curricula.

A partial listing of the high-technology programs (fields of specialization) that can be supported from the "common core" curriculum are:

Computers
Telecommunications
Computer-Aided Design
Robotics/Automated Manufacturing
Instrumentation and Control
Laser/Electro-Optics
Energy Management
Biomedical Instrumentation
Nondestructive Testing

Examples of curriculum models in two of these areas are shown in Figures 3 and 4.

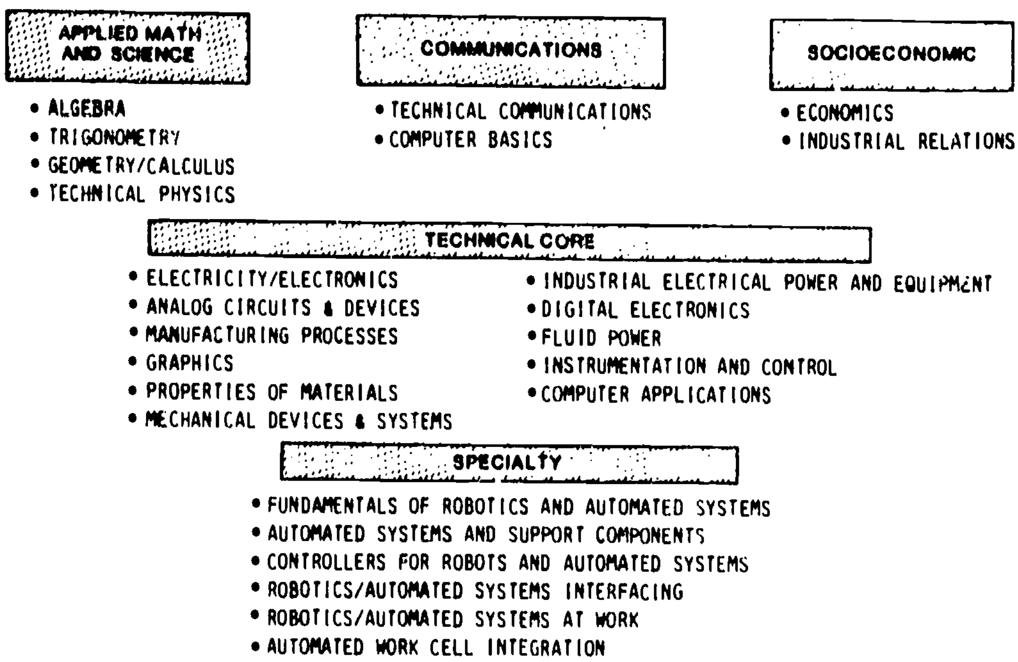

Figure 3. Curriculum model for Robotics/Automated Systems Technology.

APPLIED MATH AND SCIENCE

- ALGEBRA
- TRIGONOMETRY
- GEOMETRY/CALCULUS
- TECHNICAL PHYSICS

COMMUNICATIONS

- TECHNICAL COMMUNICATIONS
- COMPUTER BASICS

SOCIOECONOMIC

- ECONOMICS IN TECHNOLOGY
- INDUSTRIAL RELATIONS

TECHNICAL CORE

- ELECTRICITY/ELECTRONICS
- INDUSTRIAL ELECTRICITY
- GRAPHICS
- PROPERTIES OF MATERIALS
- MECHANICAL DEVICES
- ELECTROMECHANICAL DEVICES
- HEATING AND COOLING
- FLUID POWER
- INSTRUMENTATION AND CONTROL
- COMPUTER APPLICATIONS

SPECIALTY

- CIRCUIT ANALYSIS
- DIGITAL FUNDAMENTALS
- ACTIVE DEVICES AND CIRCUITS
- DIGITAL DEVICES AND TECHNIQUES
- ANALOG DEVICES AND SYSTEMS
- COMPUTER CIRCUITS AND PROGRAMMING
- DIGITAL COMPUTERS

Figure 4. Curriculum model for Computer Technology.

UNIFIED TECHNICAL CONCEPTS IN PHYSICS--It is our belief that the heart of the technical core is what we call unified technical physics. It is possible in a carefully integrated unit of physics--designed around a unification of physics principles and substantial hands-on laboratory work in meaningful laboratory measurements and experiments--to lay a firm foundation for high-technology programs. Unified Technical Concepts Physics (UTC) provides the much-needed base of knowledge and supports directly the high-tech evolution in four general areas--mechanical, electrical, thermal and fluid. The emphasis is on practical applications, real-world examples and helpful, unifying analogies of physics concepts that enable a technician to treat problems in all these systems with the same relative ease and competence.

SUMMARY

Engineering technicians are a vital link in the high-technology workforce. But they require broad-based, interdisciplinary training with a knowledge of technical principles as well as hands-on skills. Technicians of this breadth and skill level are not available within high schools, military veterans or even some community colleges. They must be developed from an educational system that includes rigorous, up-to-date associate degree engineering technology programs at postsecondary institutions.

APPENDIX F

Module Reviewers

127

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