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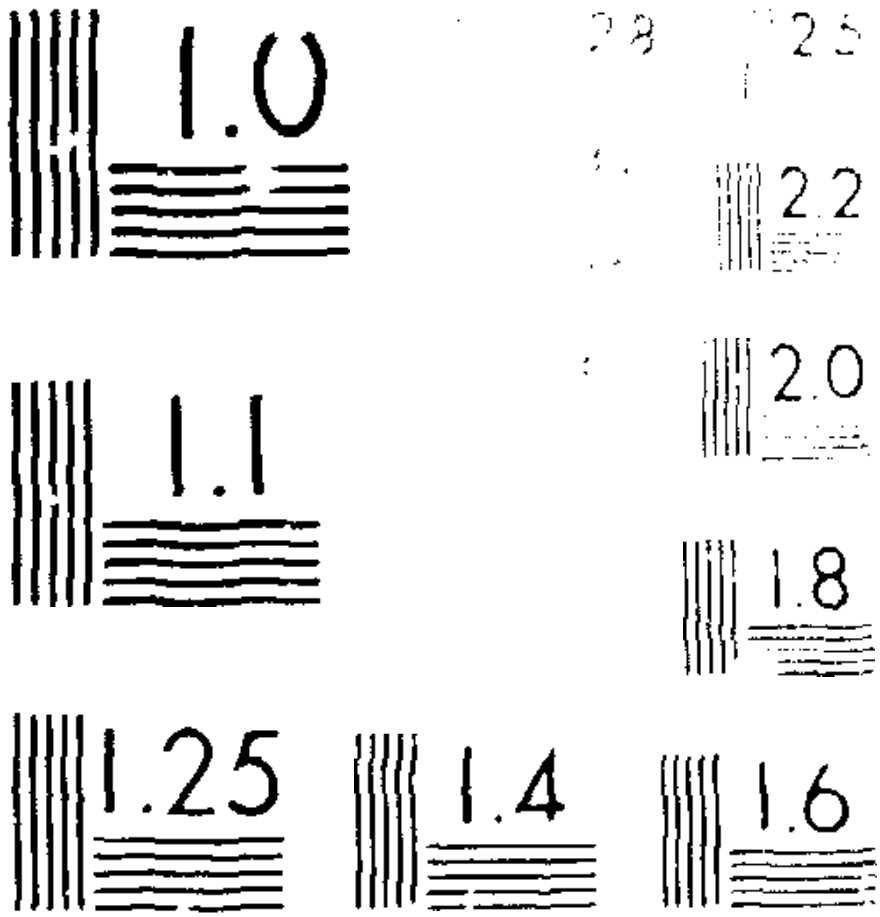
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Distr.
LIMITED

ID/WG.361/2
4 January 1982

ENGLISH

United Nations Industrial Development Organization

Workshop on the Regional Project for
Co-operative Research among Metallurgical
Research and Development Centres in
Asia and the Pacific

Jamshedpur, India, 7 - 11 December 1981

# MODERN MAINTENANCE SYSTEM ACTIVITIES*

by

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* The views expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

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V.82-20046

FOREWORD

In this report modern maintenance systems activities typical for effective maintenance in metallurgy are described and recommendations on the implementation of modern managed maintenance computer systems are proposed, based on the experience from the implementation of the Czechoslovak UNIDO large scale pilot project "Application of a Modern Maintenance System in the Iron and Steel Industry".

In the Introduction of the report UNIDO policy in metallurgical industries is outlined. The maintenance functions, organization and the structure of modern maintenance system are described in the next Part 2. An emphasis is given to a more detailed description of the above project main activities and implementation steps, these providing an ample example of modern maintenance systems activities. Part 3 describes briefly possible benefits of modern maintenance systems in manpower efficiency, spare parts and materials stock savings and increased production facilities availability, providing also concrete examples of these benefits in actual figures. In Part 4 then the recommendations for modern managed maintenance systems in the areas of manpower resources and management, training, system development, hardware and services procurement are given based on the experience from the above mentioned Czechoslovak UNIDO project.

A List of Exhibits as referred to in the text of the report is enclosed in the Annex of the report.

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# 1. INTRODUCTION

## 1.1. UNIDO Policy in Metallurgical Industries and Maintenance Systems

The United Nations General Assembly created UNIDO "to promote and accelerate industrialization of developing countries with emphasis on the manufacturing sector."

UNIDO believes that there are a series of industrial activities indispensable to sustained economic growth, the absence of any one will cripple any efforts to national progress. UNIDO considers that the metallurgical industry is one of these essential industries and the operation and maintenance activities within metallurgy is a keyfactor complementary to the efficiency of any metalworking or metal processing activity.

It is considered by UNIDO that for a fulfillment of the above objective it is necessary for industry, both existing and to be established, to be provided with the basic general services which will guarantee its operation. Thus the establishment and operation of managed maintenance systems with the characteristics described below, is indispensable to the effective implementation of any major development programme in metallurgy and operation of costly metallurgical manufacturing facilities and iron works.

The implementation of activities described in the following pages, and the projects accepted by UNIDO for execution and which are concerned all or in significant part with some aspect of managed maintenance systems activities, are the responsibility of the Metallurgical Industries Section, of the Division of Industrial Operations of UNIDO located at UNIDO Headquarters UNICITY Vienna, Austria.

The main function of the Metallurgical Industries Section is to facilitate and provide technical assistance in the installation and operation and maintenance of metallurgical industries in

developing countries. Metallurgical industries cover the production of primary metals and their alloys, in the form of ingots or slabs (iron, steel, aluminium, copper, lead, zinc, nickel, tin, etc.) and their manufacturing into semifinished and/or finished metal products (plates, sheets, rods, rails, sections, wires, tubes, castings, forgings, etc.).

The technical assistance programme of the Metallurgical Industries Section to developing countries is implemented mostly through the provision of experts, consulting firms (contractors), equipment, fellowship training and study tours in the following main fields of metallurgy:

a) Light non-ferrous metals (planning, establishment and operation of aluminium, magnesium and titanum industry):

b) Heavy non-ferrous metals (industrial processing of copper, lead, zinc, tin, nickel, tungsten, ore concentrates and primary metal products);

c) Iron and steel industry (planning, expansion and/or establishment and operation of iron and steel industries, including processing of ores to yield added value products for exports; realistic planning through the elaboration of master plans, etc.);

d) Foundry industry (planning, establishment, expansion and operation of ferrous and non-ferrous foundries with integrated mechanical workshops, etc.);

e) Metal transformation technologies (rolling, forging, heat treatment, surface treatment technologies, etc.);

f) Metallurgical know-how and technology transfer (establishment and/or strengthening of centres for metallurgical technology; development of local expertise for servicing and application in the metal industries; strengthening of modern maintenance systems, establishment of national standardisation, etc.).

In conclusion, it is emphasized that UNIDO's technical assistance and supporting activities in the fields from the metallurgical raw materials to the end products have given rewarding results and these are being stepped up on the basis of the Lima Declaration with the developing countries aiming to achieve at least 25 per cent of global industrial production in multiple fields.

The implementation of the Czechoslovak UNIDO large scale pilot project DP/CZE/77/005 "Application of Modern Maintenance Systems in Iron and Steel Industry" within the Czechoslovak National Country Programme of UNDP/UNIDO technical assistance may be used for the demonstration of the successful results achieved through the implementation of the above mentioned UNIDO/Metallurgical Section activities.

1.2. UNIDO Technical Assistance in Maintenance for Czechoslovak Metallurgical Industries

The growth of production output in Czechoslovak metallurgical industries is represented by a steady 5.5 % increase per year during the last decade 1971-80 and it has been anticipated that this rate will even be accelerated during the next Five Year Plan 1981-85. The costs of maintenance and repairs monitored throughout this period showed a similar pattern whilst the value of modern new installed production facilities and equipment has more than doubled; in parallel, the demand for both qualified maintenance manpower and management and planning staff has grown, too. Therefore, the necessity for rationalization and improvement in maintenance productivity and maintenance planning and management has arisen. In order to meet these needs of metallurgical industries within the framework of the Czechoslovak industry development plans the project "Application of a Modern Maintenance System in the Iron and Steel Industry" (Code No. DP/CZE/77/005) was agreed to become a part of the Czechoslovak National Country Programme of UNDP/UNIDO technical assistance

in early 1977. The project starting date was agreed as June 1st, 1979, with estimated duration 2.5 years, i.e. project completion date being November 30th, 1981.

Czechoslovak Federal Ministry of Metallurgy and Heavy Engineering represented by INORGA Research Institute for Industrial Management and Automation was appointed as a Government Cooperating Agency, providing the requisite framework, project management and counterpart organization in cooperation with VSŽ - East Slovakian Steel Works Košice, the latter providing direct counterpart platform for the proposed pilot maintenance computer control system development and implementation.

The Government of ČSSR agreed to utilize for the project the existing computer facilities with the counterpart organizations to the value of US $ 2.5 million and to provide additional inputs of the total value CS Crowns 17.1 million to cover for the project implementation requirements - these comprising inter alia the provision of salaries of counterpart personnel, building and both expendable and nonexpendable equipment, computer time costs for programmes development, training costs, etc. These planned Government inputs were in the course of project implementation duly increased by 33.9 % to the total of CS Crowns 22.9 million to cover the increased requirements of this large scale pilot project, in particular in the field of training, building habilitation, installations and nonexpendable equipment. UNDP/ UNIDO originally agreed contribution to cover the project requirement in the field of training, consulting services and nonexpendable and expendable equipment was US $ 0.912 million. These inputs were during the project implementation increased by 16.4 %, the total actual contribution thus being US $ 1.062 million.

The objective of this report is to describe modern maintenance systems activities typical for effective maintenance of production facilities in metallurgical industries, in particular those in steelworks, and to provide recommendations on the implementation of modern managed maintenance based on the experience from the above mentioned large scale pilot project implementation under the auspices of UNIDO technical assistance.

## 2. MODERN MAINTENANCE SYSTEMS ACTIVITIES

### 2.1. Maintenance Function and Organization

The primary function of a Maintenance Department is to maintain costly plant processing equipment and building facilities in an acceptable, operating and safe condition. The performance of this function requires technical expertise involving skilled craftsmen supported by maintenance shop equipment required in the repair of parts and/or their manufacture and efficient planning and management. The maintenance activities utilized to perform this function are therefore generally classified and referred to as maintenance shop services, maintenance field services and maintenance planning services.

a) Shop services are those associated with:

- The repair and reconditioning of parts and assemblies involved in equipment breakdowns.
- The manufacture of new parts for replacement of spare parts inventories.

b) Field services are those associated with:

- The installation of equipments and parts.
- The rehabilitation of building facilities.
- The replacement of worn or broken parts.
- The development and operation of a preventive maintenance system including lubrication, inspection and testing.

c) Maintenance Planning Services are those associated with:

- The development and operation of a planning, processing and scheduling and monitoring systems for all work orders prepared for maintenance shop and field activities.

- The development and operation of a spare parts purchasing, stocking and inventory control system.
- The development and operation of costing system and budget for maintenance shop and field activities.

In order to provide proper management of a Maintenance Department an organizational structure that sets forth clearly lines of authority and specifies accurately the inherent responsibilities of the management and planning positions involved is required.

The organization structure will have a major effect on both plant availability and maintenance costs. In some plants, maintenance activities are decentralized, with specialists in the production departments. This self-sufficiency in maintenance can lead to overstaffing, and the increased specialization of craftsmen in many trades has caused many companies to create centrally organized maintenance functions, and to increase the automation of their workshops.

This centralization, however, brings about difficulties of its own. For onsite maintenance, it can be increasingly difficult to organize the maintenance work force in parallel with production. This often gives rise to unsatisfactory organizational structures, in which the technical responsibility that should be concentrated in one unit is spread over a number of organizational units.

When computer system is applied to maintenance planning and management, the advantages of decentralized plant maintenance can be combined with those of centralized maintenance. The more efficient use of manpower, the better distribution of the work load, and the possibilities of better long-term planning that centralization brings, can still be possible without physically removing the maintenance work force from the production areas they logically belong to.

Other factors influencing maintenance organization are:

- Location. In some areas, external maintenance crews may be used during peak loads, or they may take over entire specialized maintenance tasks. Neighbouring plants also commonly loan spare parts to each other in an emergency.

- Technological standards. In some plants, advanced technology means that full-time maintenance specialists are required, making it possible to rely on outside help.

- Plant size. Small plants cannot fully employ the specialist they need. This leads them to build up large reserves, for example, of spare parts, and, in emergencies, to have to call in outside specialists under contract.

- Manpower. If work loads fluctuate, and if there are no stabilizing factors, external craftsmen can be called in during operating peaks. In this way, maintenance costs can be kept low during normal operating periods.

- Risks of breakdown. Equipment with a high risk of breakdown requires substantial backup services, in the form of standby facilities and a much larger maintenance work force.

## 2.2. Modern Maintenance System Structure

Based on the general maintenance function as described above, the following functions and/or subsystems essentially create the structure of a modern managed maintenance system:

Maintenance Work Order Creation:

- job requests
- verification and work order generation
- dispatching

Maintenance Planning:

- plant catalog
- preventive maintenance planning
- repair planning
- equipment lay-offs planning
- material requirements planning
- manpower requirements planning
- maintenance cost planning

Inventory and Stores Management:

- spare parts catalog
- inventory recordkeeping
- inventory control
- parts and materials allocation
- disbursement

Purchasing of Spares, Materials and Services:

- purchase requisition
- purchase order generation
- vendor data update
- followup

Spare Parts Manufacture and Reconditioning:

- drawings
- bills of material
- routing operations
- work stations
- capacity planning and operation scheduling
- shop floor monitoring and control

Maintenance Work Order Scheduling:

- job selection
- CPA method application
- capacity planning and job scheduling
- releasing maintenance jobs
- dispatching
- rescheduling

Maintenance Work Order Monitoring:

- equipment lay-offs monitoring
- job status reporting
- manpower loading and efficiency
- maintenance cost monitoring

History and Analysis:

- job completion reporting
- maintenance cost analysis
- equipment analysis
- preventive maintenance and planned repair cycles and standards development

This modern maintenance syster structure and additional specialized maintenance functions including the necessary system hardware and software support have been embedded into the implementation of Czechoslovak UNIDO project DP/CZE/77/005 "Application of a Modern Maintenance System in the Iron and Steel Industry" (hereinafter called Project only) through a comprehensive set of the following inter-related Project activities:

A1 Project management and planning functions

A2 Planning preventive maintenance and repairs

A3 Planning spare parts, semiproducts and materials

A4 Capacity planning and scheduling of maintenance work

A5 Inventory control and materials and spare parts purchasing

A6 Spare parts manufacture planning and control

A7 Maintenance monitoring

A8 Centralized Data Bank and coding systems

A9 Teleprocessing and application transactions support

A10 System hardware support

A11 Maintenance economics

A12 Experimental laboratory

A13 Microprocessor based diagnostics systems

A14 Computer aided parts programming

A15 Operational Research modelling

The reasons for the specification of and breakdowning the Project's work plan into these activities resulted from a detailed feasibility study and analysis.

These Project activities may be divided into five basic categories:

(1) Overall functions: A1
(2) System development nucleus: A2, A3, A4, A5, A6
(3) System integration: A7, A8, A9
(4) Hardware support: A10, A12
(5) Specialized features: A11, A13, A14, A15

The relationship among the Project activities is given in Exhibits 1 and 2, depicting also the links among Project activities and/or subsystems with other existing corporate computer information systems.

Note: The reader not fully familiar with computer system development work should pay attention to the following explanation of the nature of the system development. This will enable him to understand fully the Project activities and achievements.

First of all we have to realize that the end product of the system development project is not a training centre, institute or working factory but an "invisible" product - system and acquired know-how supported by installed hardware and developed software. Therefore, it is also more difficult to monitor and evaluate its progress and achievement of objectives. The only possible approach is to follow different stages of system development. These may be summarized as follows:

1. Fact finding - analysis of the current system operation.

2. Feasibility study - where the basic concepts of new system are evaluated.

3. System design specification (so called "technical project" in Czechoslovak terminology) - where all algorithms, inputs and outputs are fully specified.

4. Programming phase - the system specs are "translated", coded into the language of the computer.

5. Programme testing and debugging, data collection.

6. Introductory system implementation (testing) and user training and documentation.

7. System implementation.

8. System operation and maintenance (including improvements of running programmes and update).

All these stages are part of system development and life cycle, in fact a continuous process, with feedback from any stage to the previous stages. From this viewpoint, it is necessary to evaluate the activities since phases 1 - 3 (i.e. until programming phase) could be also carried out without computer facility or without actually running any computer programmes. However, if we develop a stepwise implementation plan, in certain stages it is possible to overlap activities using same manpower, i.e. both system design work, programming, system testing and implementation could be carried out simultaneously. This note holds especially for Project activities A2 - A9. The subsystems of the overall maintenance system corresponding to these activities were broken down into priority modules and the above described system development approach was then applied to these priority modules. In this way it was possible to use most efficiently both qualified manpower and achieve stepwise, gradual system implementation which would otherwise not be possible.

**Because it was necessary to respect both the technical nature of the computer systems development process and the structure of the overall maintenance system and Project objectives, the above listed activities had to be implemented in the given set.**

**From the above set of activities, A1 provides requisite framework for the overall Project - project planning, coordination and management, system documentation, training and transfer of know-how. The following five activities A2 - A6 represent the primary functions of the maintenance system:**

- **Planning preventive maintenance and repairs**
- **Planning spare parts, semiproducts and materials**
- **Capacity planning and scheduling of maintenance work**
- **Inventory control and materials and spare parts purchasing**
- **Spare parts manufacture planning and control**

System integration and necessary links are provided by the next four activities A7 - A10, in particular the maintenance process monitoring in all these primary maintenance functions (A7), development of coding systems and data bank integration (A8), teleprocessing and transactions development (A9) and the hardware support, i.e. both central computer systems, communication network and terminal clusters (A10). The majority of these functions were developed for on-line system mode of operation which enables not only flexible operations management tool but also efficient combination of centralized and decentralized organization of maintenance.

Specialized modern features of the maintenance system are introduced through the implementation of activities A12 - A15. Activities A12 and A13 provide most up-to-date means of preventive maintenance - microprocessor based plant condition monitoring and diagnostics; A14 applies computer graphics to spare part programming and A15 is concerned with the application of Operational Research models in maintenance problems, in particular the Simulation and Network Analysis approach. The maintenance economics and cost/benefits analysis methodology are provided by A11.

A more detailed explanation of the above characterized activities, specifying activity objectives, technical nature and outputs and related to the Project immediate objectives and/or outputs is given below. From these will also follow recommendations for the development and implementation of similar modern integrated managed maintenance systems activities.

2.3. Czechoslovak UNIDO Project Main Activities

Planning Preventive Maintenance and Repairs (A2)

Activity Objectives:

Development and implementation of system modules for planning of inspections and preventive maintenance, repairs and overhauls and facility lay-offs with regard to maintenance ordering, inventories, spares manufacture, available manpower, maintenance costing and main production planning and/or scheduling.

Activity Outputs:

For main production facilities, this activity, periodically or in enquiry mode, provides for the following:
- long term plans of preventive maintenance and repairs (optional month, quarter, year or five-year horizon);
- long term gross requirements for spare parts/assemblies;
- gross plans of maintenance capacity requirements;
- maintenance costs planning.

In interactive mode and/or periodically in batch mode, this activity provides data entry, update and printouts for:
- maintained facilities catalog (covering production lines, machines, assemblies, parts);
- preventive maintenance/repairs cycles catalog;
- operations-and-standards-of-maintenance-work catalog;
- maintenance work demands;
- maintenance work orders;
- job orders for maintenance work orders;

and also, enabled are enquiries in on-line and batch modes.

Planning Spare Parts, Semiproducts and Materials (A3)

Activity Objectives:

Development and implementation of system modules for assemblies, spares and materials requirements planning for both maintenance and reconditioning purposes, including consumption feedback and deviations analysis.

Activity Outputs:

This activity, in interactive mode and/or periodically in batch mode, and in full variety of replacement parts and repaired/reconditioned/manufactured assemblies and materials needed, enables data entry and/or update for:
- variety of spare parts, assemblies, materials and semiproducts;
- demands;
- demands balancing;
- reservations to cover demands;
- recommendations to purchase/manufacture/recondition.

Periodically, in enquiry mode and/or in on-line mode, this activity provides for the following management information:
- catalog of spare parts, assemblies, materials and semiproducts (with all relevant characteristics);
- demands survey (including how-they-are-arranged-for survey);
- reservations survey (with respect to stockpiles, purchase orders, and internal orders for manufacture, reconditioning and installation);
- net requirements balance;
- recommendations for purchase;
- recommendations for internal manufacture, reconditioning and installation.

This activity is closely related to activities A2 and A5 in particular - in order to calculate gross requirements and then to match them with available stock to obtain net requirements (these either purchased or manufactured), the inventory control modules (A5) are prerequisite.

Capacity Planning and Scheduling of Maintenance Work (A4)

Activity Objectives:

Maintenance manpower planning according to the maintenance and spares manufacture requirements and uniform manpower utilization objective, including actual usage monitoring and work effectiveness and productivity monitoring and evaluation.

Activity Outputs:

For large scale repair operations, overhauls and revamps of production lines and machines, this activity periodically, in enquiry mode and/or in on-line mode, provides for the following:

- network catalog (network graphs);
- maintenance capacity resources catalog;
- network scheduling;
- resources balance for scheduled networks;
- job orders for releasing orders and jobs;
- preventive maintenance and repair orders schedules with start and completion terms, including job orders for maintenance work orders;
- survey of scheduled joint operations (on resources basis);
- resources catalog;
- survey of resources capacity loading;
- maintenance orders and job orders for release;
- work and accounting documents;
- survey of fulfillment of job orders for maintenance orders.

Inventory Control and Materials and Spare Parts Purchasing (A5)

Activity Objectives:

Development and implementation of a spare parts inventory control system, blocking of items for maintenance and manufacture orders, stockyard space utilization and the purchase monitoring and vendor data update.

Activity Outputs:

In interactive mode and/or periodically in batch mode, this activity enables data entry and/or update for:
- the variety of spare parts, assemblies, materials and semiproducts;
- the vendors;
- purchase orders and their items;
- internal orders for manufacture, reconditioning and installation and their items;
- reservations from stockpiles, from purchase orders and internal orders;
- inventory transactions and physical inventory takings;
- store locations.

This activity, periodically, in enquiry mode and/or in on-line mode, and in the full variety of replacement parts and repaired/reconditioned/manufactured assemblies and materials needed, provides for the following management information:
- catalog of spare parts, assemblies, materials and semiproducts (with all relevent characteristics);
- survey of the level and movements of inventories, including stockplace transactions (receipts, dispatches);
- reservations survey (with respect to stockpiles, purchase orders, and internal orders);
- basic documents for physical inventory takings and physical inspections of the stockpiles (lubricants, protective varnish etc.);

- trends in requirements, purchase, manufacture, consumption;
- catalog of storeplaces;
- survey of available and occupied storeplaces and movement frequency;
- vendors catalog;
- survey of purchase orders and their items;
- survey of internal orders for manufacture, reconditioning and installation;
- survey of deliveries fulfillment.

Spare Parts Manufacture Planning and Control (A6)

Activity Objectives:

Development and implementation of a spare parts manufacturing and reconditioning planning and control subsystem, including drawings, bill of material processor, process routing, work center capacity loading and scheduling, shopfloor monitoring.

Activity Outputs:

For control of manufacture and reconditioning of spare parts, assemblies and semiproducts in central maintenance shopfloors, this activity, periodically in enquiry mode and/or in on-line mode, provides for the following information:
- catalog of products and their components, including costing;
- drawing documentation catalog;
- catalog of manufacture, reconditioning and installation operations;
- catalog of shopfloors, assemblies, subassemblies and individual machines and workplaces for manufacture, reconditioning and installation;
- rigg catalog;
- survey of internal orders for manufacture, reconditioning and installation with order items included;

- schedule of internal orders and their items, including the start and completion terms for orders and products;
- survey of machines and workplaces capacity loading;
- short-term operations schedule for orders and machines;
- survey of to-be-released orders and operations;
- work accounting and dispatching documents;
- survey of schedules fulfillment for orders, products and operations.

This activity implementation as well as the previous A5 is most promising as for the transfer of know-how to machine engineering and other works.

Maintenance Monitoring (A7)

Activity Objectives:

Development and implementation of a subsystem for allocation, capacity planning and scheduling, order handling, progressing and coordinating. The subsystem also includes monitoring of maintenance jobs and/or costing and the resulting analysis of statistical data and corresponding standards update.

Activity Outputs:

Implementation relates to the objectives as given under the activities A2 through A6 while activity A7, in interactive mode and/or periodically in batch mode, provides data entry, update and printouts for:

- status and time utilization of Work's production facilities, and maintenance equipment and personnel;
- production facilities idle times and failures with evaluation included, based on time, type, cause, machine break down;
- progress of scheduled orders fulfillment.

In the area of historical files preparation and analyses of them, this activity, periodically, in enquiry mode and/or in on-line mode, provides for the following management information:

- changes history for maintained facilities (production lines, machines, assemblies, parts);
- maintenance work history for production lines, machines, assemblies and parts;
- listings of jobs not completed;
- idle time and failure statistics;
- changes in cycles, operations schedules and standards for maintenance work;
- history of spare parts purchases, assemblies, materials and semiproducts;
- history of manufacture and reconditioning of spare parts, assemblies, materials and semiproducts,
- consumption history for spare parts, assemblies, materials and semiproducts;
- changes in drawings, bills of material and manufacture/reconditioning operations.

This activity A7, like the following activities A8 and A9, provides the integration of the modules and subsystems that are results of the previously mentioned activities. In this case, A7 the monitoring functions for all the previous activities.

System Software Program Support (A8, A9)

Activity Objectives:

Development and implementation of an overall centralized Data Bank and coding systems servicing maintenance subsystems and/or activities as described above (A2 - A7). Another important part is teleprocessing and application transactions support, i.e. a system for transactions processing for application needs of the maintenance subsystems and/or activities using a teleprocessing network and on-line man/machine enquiry concepts.

Additional software program support includes computer vendor supplied system software like IMS Operating System, Data Base Management System, application products, MRP, PMS, CAPOS, CLASS, etc.

Activity Outputs:

Software for initial loading and maintenance of:
- data catalog (including identifiers and codes);
- maintained facilities Data Bank;
- operations-and-standards-of-maintenance-work Data Bank;
- maintenance-work-orders Data Bank;
- Data Bank of spare parts, assemblies, materials and semiproducts;
- Data Bank of vendors for spare parts, assemblies, materials and semiproducts;
- Data Bank of manufacture and reconditioning of spare parts, assemblies and semiproducts;
- rigs Data Bank;
- replacement-assemblies-circulation Data Bank;
- remaining files,

of course with necessary checkup procedures/data protection included.

Software for teleprocessing:
- terminal network control independent of application programs;
- transactions processing independent of the types of the terminals used;
- traffic control for input/output messages;
- dialogue (interactive) support for application programs;
- dialogue monitor as a tool to increase programming productivity;
- special QUELA dialogue language enabling simple access to information in users Data Base.

System Hardware Support (A10, A12)

Objectives and Outputs:

The objective of these activities is to meet the requirements of the main maintenance subsystems in computer and terminal hardware (processing, storage, communications).

The outputs include central computer configuration installation of IBM 370/145 system extens on of main memory, CDC 100 MByte external disk storages, magnetic tapes, installation of IBM teleprocessing terminal equipment (display stations, printers, control units, modems, etc.), teletype equipment, see Exhibits 3, 4 enclosed. Also two terminal clusters were temporarily installed for both interactive system design and on-line program development. This enables increased productivity of project system designers and programming personnel (see Exhibits 5, 6 enclosed). Later these terminal clusters were transferred to maintenance user areas.

Technical system support for the development of microprocessor and computer aided parts programming applications was provided through the establishment of experimental laboratory equipped with Plessey 34 minicomputer configuration, MDS 231 micro-computer development system and SBC INORGA application micro-computer configurations, see Exhibits 7, 8 enclosed.

Microprocessor Based Diagnostics (A13)

Activity Objectives:

Development and implementation of a multipurpose diagnostics microprocessor-based system for applications in sequentially operating metallurgical production facilities. The system to provide unbiased data on production facility's reliability and breakdown analysis for preventive maintenance purposes.

Activity Outputs:

A system, which meets the objectives, has been programmed and applied for coiler-area diagnostics monitoring in a hot strip mill at East Slovakian Steelworks. For this system implementation, BSC OS know-how was utilized using a modified MICROSECOM system. This modified MICROSECOM system, built around a SBC 80 microcomputer and equipped with a printer and a tape cassette storage, has been used to monitor a number of two-state variables, to record changes and, if a case should be, to provide post mortem data in coiler area. The system can be extended by incorporating also analog inputs.

Computer Aided Parts Programming (A14)

Activity Objectives:

Application of advanced computer aided parts programming for spare parts manufacture, the use of interactive computer graphics for development and validation of programs for spare parts manufacture using NC machines, as well as the entry and validation of geometrical data on the parts manufactured and/or their possible modifications.

Activity Outputs:

A system was developed that fully meets the objectives given above. The INGE 2 system (INteractive GEometrical system for 2 and 2-1/2 dimensional parts) is an interactive part-programming system easy to understand and use. The INGE 2 makes geometrical definitions easy and creates the ISO recommended CL (cutter location) data files. A certain developed general postprocessor module corresponds to these files, which makes the development of new postprocessors (programs for a particular machine tool/NC system) quite simple. This approach cuts drastically the engineering drawing and technical preparation of spare parts NC tool manufacture.

Operational Research Modelling (A15)

Activity Objectives:

Development, programming and implementation of simulation models of production cycles in connection with maintenance planning with the purpose of coordination of the respective plans. Experimental mathematical modelling, in particular the use of CPM and network analysis methods for maintenance and Project management purposes.

Activity Outputs:

Mathematical model for the simulation part above was formulated, developed and programmed using SIMULA 67 compiler. The necessary statistics were collected, a simulation system of steelplant/ rolling mill area was created and is fully implemented and available for the use for maintenance planning and production coordination purposes at East Slovakian Steelworks.

Mathematical models of O. R., network analysis method in particular, have been applied for both project network planning and large repairs and overhauls purposes. The application of network analysis methods was generalized into the form of a multipurpose network analysis computer package that is available for further transfer of know-how.

## 2.4. Maintenance System Implementation Steps

The system development and implementation depends to a large extent upon the nature of the existing systems, both manual and computerized ones, the priorities of individual subsystems and/or modules decided by the management and during the design stage, available financial, hardware and human resources, maintenance organization, and many other factors. Nevertheless, the implementation sequence described below is typical for modern computer based management systems and follows a clear and simple logical pattern. The individual implementation steps, although many times overlapping and interacting, are given as follows:

### Step 1

Stores inventory accounting and control is the recommended starting point for a maintenance system, and the parts usage history and inventory data acquired during this step will serve for the enquiry function of the spare parts and materials application, in the next step.

### Step 2

When a work order creation system is put into operation, the access to the stock number data base will allow work orders to be approved with full knowledge of the availability of parts. Dispatching of emergency work requests can be implemented at this time.

Job reporting can also be implemented since the data structure of this application is closely associated with the work order.

### Step 3

From the data base built up from work order entry and job reporting, equipment and maintenance costs can start to be

monitored and analysed. Obviously it is going to take a certain amount of time before there is sufficient data to be able to produce significant analyses.

Step 4

With access to the equipment history and spare parts data bases, the maintenance planner can start developing job plans and preventive maintenance schedules for machines and production units.

As these plans are developed, they are stored in the data base and can be retrieved by equipment number, equipment class or condition, component, or action code for the type of report.

Step 5

The catalogue of job plans can represent work standards, or the work standards can be extracted from the job plans. Once these standards are established, it is possible to compare the actual with the planned activity in order to report and analyse performance. This analysis can be type of maintenance, plant area, or craft.

Step 6

The next step might to be to generate and update preventive maintenance schedules through analysis of the equipment history.

Step 7

In planning the job, an estimate is made of the manpower required. Once this is done, the jobs can be accumulated into job catalogue, arranged by priority, and scheduled according to available maintenance manpower. This is generally done weekly and allows for a great deal of interaction between maintenance and production management.

## 3. BENEFITS OF MODERN MAINTENANCE SYSTEMS

The potential benefits of a computer based modern maintenance system depend on management objectives and constraints that it is designed around, and the existing systems it replaces or complements. For existing equipment, the main objectives are:

- to increase manpower utilization and efficiency,
- to reduce spare parts and materials stock,
- to increase production facilities availability.

For new equipment and especially that which incorporates advanced or complex technology, it may not be possible to meet availability targets without really effective maintenance management at all.

### 3.1. Increased Manpower Efficiency

| | |
|---|---|
| Data retrieval without traveling | Reducing travel time |
| Automatic copy of data on work-order document | Reducing complexity of work orders generation |
| Precise work-order instructions | Reducing nonproductive time |
| Complete and timely availability of spare parts and tools | Reducing number of interruptions |
| Reduced spare parts delivery time | Reducing waiting time, reducing workers idle time |
| Balanced capacity planning | Reducing time between job assignments |
| Simple reporting | Reducing clerical work |

3.2. Reduced Spare Parts and Materials Stock

| | |
|---|---|
| Updated "where-used" lists<br>substitute parts stock<br>movements analysis | Suppressing excess or<br>obsolete parts.<br>Standardization |
| Timely reservation of 70 %<br>of spare parts<br>Known maximum lead time<br>Deferred stock replenishment<br>Immediate record of movements | Decreasing average<br>stock level<br>- decreasing minimum stock<br>- decreasing the number<br>of replenishment orders |
| Stock level check<br>at each disbursement | Decreasing the number of<br>"out-of-stock" situations |
| Automatic check of unused or<br>repaired parts to be returned<br>Timely decision for repair | Decreasing spare parts usage<br>- suppressing hidden stock<br>- increasing return |

3.3. Increased Production Facilities Availability

| | |
|---|---|
| Preventive or planned maintenance<br>- work order scheduling<br>- fast selection and dispatching<br>- precisely known capacity required | Decreasing machine idle time<br>- work orders grouping<br>- work orders ready in case<br>of idle time |
| Equipment monitoring<br>- inspection, measurements<br>- checks during idle time | Reducing the number of<br>breakdowns |
| Historical data processing<br>- preventive operations,<br>verification check-lists<br>etc. | Reducing the number of<br>breakdowns |
| Systematic work preparation | Decreasing machine idle time |

Apart from the intangible benefits, such as better information for decision making, the benefits of a computer based maintenance system are expressed in net savings over a number of years, e.g. the system life cycle. These are arrived at by subtracting estimated implementation and operating costs from estimated gross savings.

The monitoring of costs and benefits and their analysis achieved throughout the Czechoslovak UNIDO Project development and implementation can be summarized as follows:

| | | |
|---|---|---|
| - annual savings due to the lower inventory levels of spare parts | CS Crowns | 11.000,000 |
| - annual savings due to the increased volume of assemblies an spare parts reconditioning | | 6.880,000 |
| - annual savings due to the lower imports of spare parts | | 18.500,000 |
| - annual savings due to the increased productivity of standardized assembly repairs (150 - 160 employees) | | 12.400,000 |
| - annual savings due to the lower downtimes of key production facilities | | 9.239.000 |
| - annual savings due to the increased facility loading in the spare parts manufacture area | | 1.360.000 |
| - annual savings due to the improved planning of repairs and manpower utilization (90 - 95 employees) | | 3.700,000 |
| - annual savings due to the lower rescheduling of maintenance jobs and transportation times | | 240,000 |
| Total annual savings | CS Crowns | 63.319,000 |

Considering the overall costs of CS Crowns 115.678 million for system development, routine operation and maintenance within the so called economic life of the system (i.e. period of 1979-89) and the corresponding total savings of CS Crowns 296.114 million stemming from the gradual system implemetation during that period, the return ratio is approximately 3 years, i.e. the index of economic effectiveness per one CS Crown is 296.114/115.678 = 2.56 CS Crowns

## 4. FINDINGS AND RECOMMENDATIONS

Based upon the experiences on the implementation of the Czechoslovak UNIDO Project which represented the development and implementation of a modern managed maintenance system, the following recommendations can be made:

### 4.1. Human Resources

The effort of Project personnel represented the main asset of the Project. There were about forty five men working currently on the Project (with sometimes more people, sometimes less), highly qualified systems analysts, designers, application programmers, system programmers, and users. High qualifications resulted in the possibility of considerable savings in software development that could not be otherwise achieved. We could rely upon our own resources, developing our own operating system, STELA, especially tailored for teleprocessing, at East Slovakian Steelworks, own versions of operating systems based on MRP, independently of software houses and independently of delivery times, licensing conditions, and so on. This also holds for the APROS documentation package, and network analysis package, cost monitoring systems, etc. Also the enthusiasm and cooperative spirit of counterpart personnel rendered possible high concentration of manpower at critical time periods, to balance the delivery delays, etc. An effective teamwork organization is a prerequisite of a modern system development and implementation (see Exhibit 9). It is to be recommended to incorporate the user implementation team into the system design team as well using the programmers as a pool for the application programs development.

### 4.2. Training

The computer based modern maintenance system development requires an extensive programme of training of system designers and analysts, programmers and users and management in all major phases of system development and implementation.

As for training and organization of study tours, we found it is essential to organize the training as soon as possible, through all possible channels: bilateral contacts, consulting company, UNIDO Training Branch. Also it is very useful to use opportunities like large conferences and exhibitions for the acquisition of necessary know-how, and professional courses of professional bodies and software houses. It is also very useful in computer project to use training facilities of the vendors of computer equipment, and in fact, we succeeded in our case to get certain discounts with these vendors, not always at the price level of the equipment but on the level of free specialized training. Every bargaining with the computer vendors should include this item. Regarding the internal trainings, it is very useful to use the know-how gained by the people who took part in the study tours and to transfer their acquired know-how to other people working on the Project. This we carried out in a number of short-term internal seminars.

4.3. System Development and Implementation

For large scale system development, the step-by-step development and implementation is absolutely essential, determining carefully the choice of priority subsystems and/or modules together with integrated activities.

The system should be designed modular enough to render possible this above mentioned gradual implementation.

Modern system design and development approach based on both interactive, computer-based system and programs development (using different terminal clusters for the system design and program development and testing purposes) proves to be highly efficient and essential to increase EDP personnel productivity and to meet tight schedules. Also, it is very efficient and useful to use the computer as a project management tool for both network analysis, monitoring of costs and computerized documentation.

Great attention must be paid to the selection of the pilot implementation areas, according to the limitations of the equipment in the field, manpower resources, data collection possibilities, economic benefits and criteria dependent on their weights and/or priorities different in individual cases. If we are able to achieve gradual implementation using priority modules, reasonable balance between the overall implementation and pilot implementation should be made. However, the necessary condition is that the system should be general enough to be implemented in all plant application areas.

4.4. Hardware and Software Procurement

Concerning the hardware and software procurement, it is necessary to do the bargaining and hold the discussions of the proposals quite in advance, because this is not only a question of prices and long delivery times, but also of licensing, and since it is already a system work to prepare a good tender - the necessary hardware must suit to the system development objectives - it is advisable to start with the preparation of the tenders as soon as possible. In our case we did it twelve months prior to the Project start and it was just right, regarding the 2.5 years duration of the Project.

In the evaluation of hardware equipment the following factors beside the above mentioned should be considered: price/performance ratio, compatibility and modularity, maintainability, convenience of using industrial standards, and future growth.

4.5. Consultancy Services

For consultancy purposes, some highly specialized functions and/or the overall system development management, the consultancy and expert services may be required based on the project objectives and needs. Firstly, the choice of consultancy company and/or

expert is important. The consultancy company beside being technically competent and financially acceptable should not be as large as to lose the interest for the professional objectives of the project, i.e., the system development, and to concentrate on business fees only. It is necessary to choose a company that is genuinely interested upon the project. Secondly, it is necessary to establish good relations with the advisers and experts, to create a good atmosphere for the sound cooperation and joint system development. Thirdly, the consultancy organization should also be utilized for the project training needs, as mentioned above.

LIST OF EXHIBITS

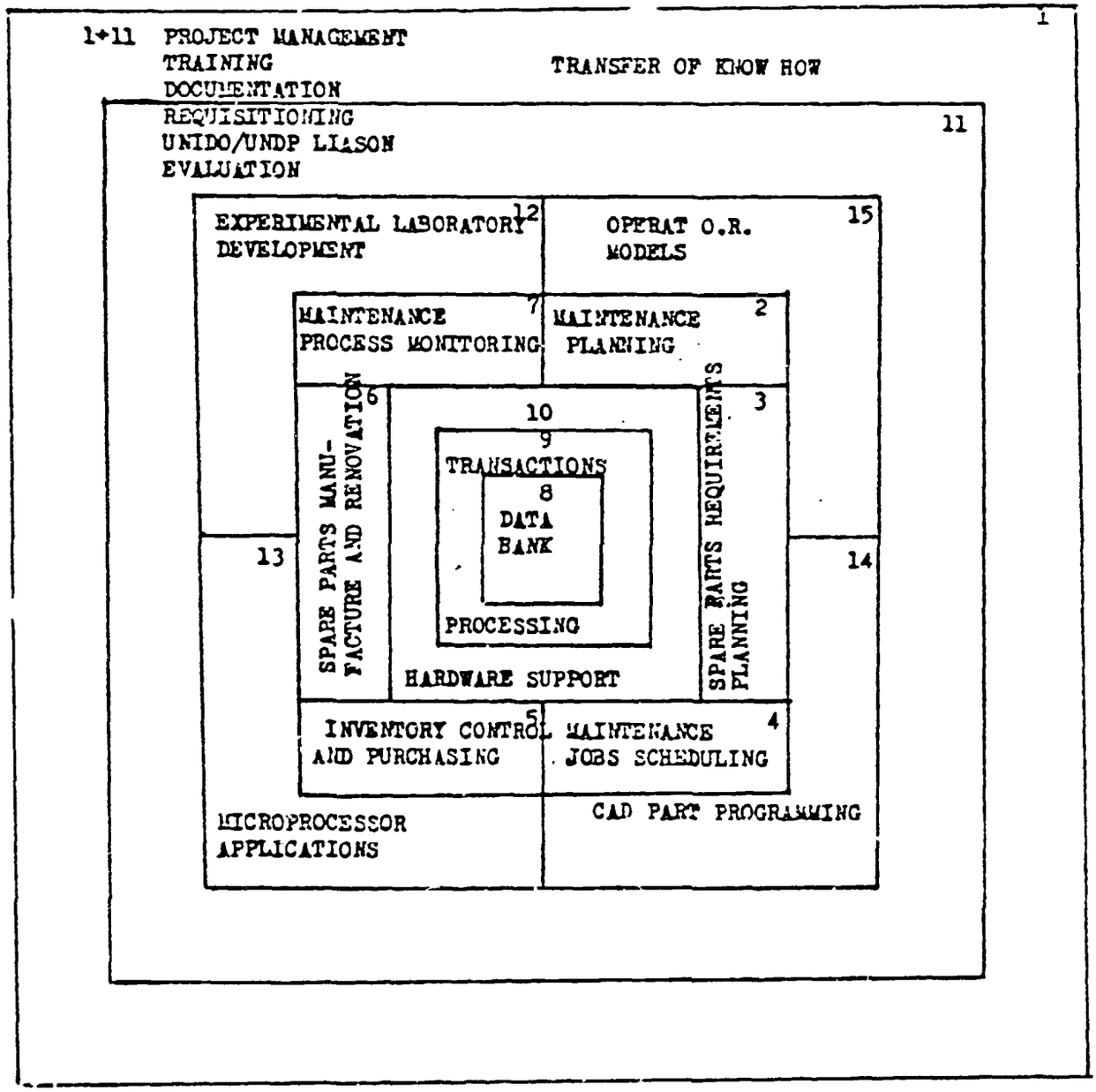


EXHIBIT 1 PROJECT ACTIVITIES

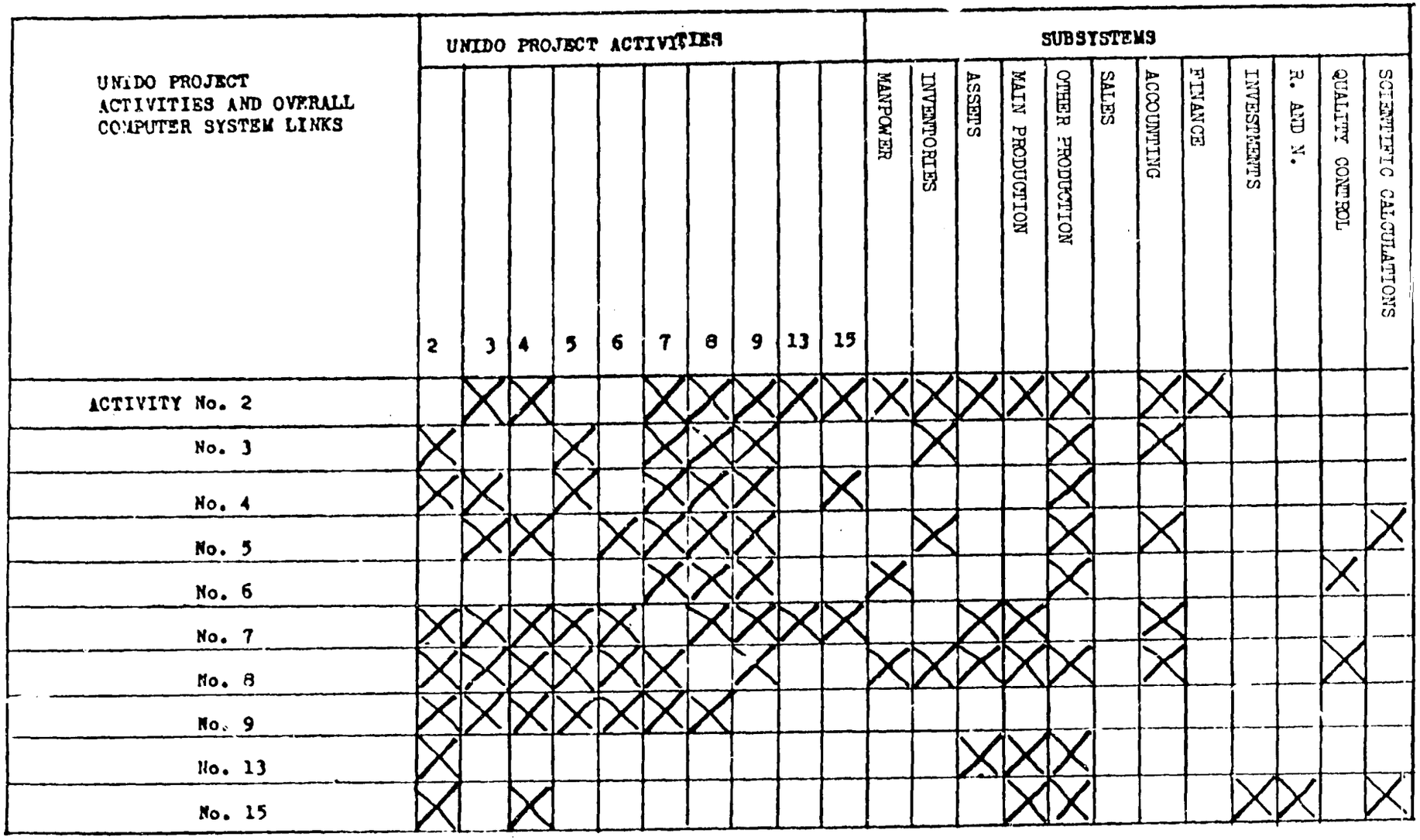


EXHIBIT 2 PROJECT ACTIVITIES AND ENVIRONS

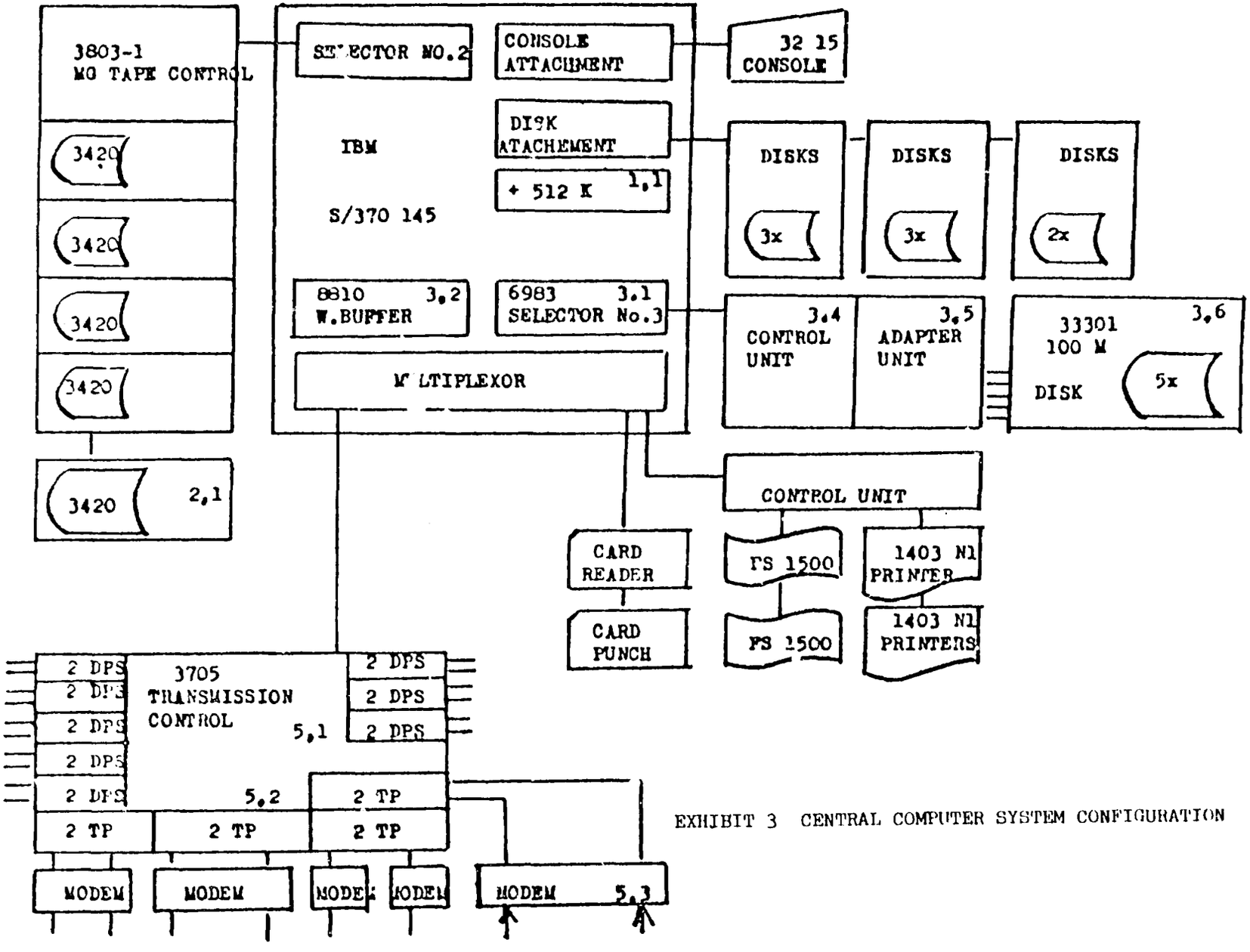


EXHIBIT 3 CENTRAL COMPUTER SYSTEM CONFIGURATION

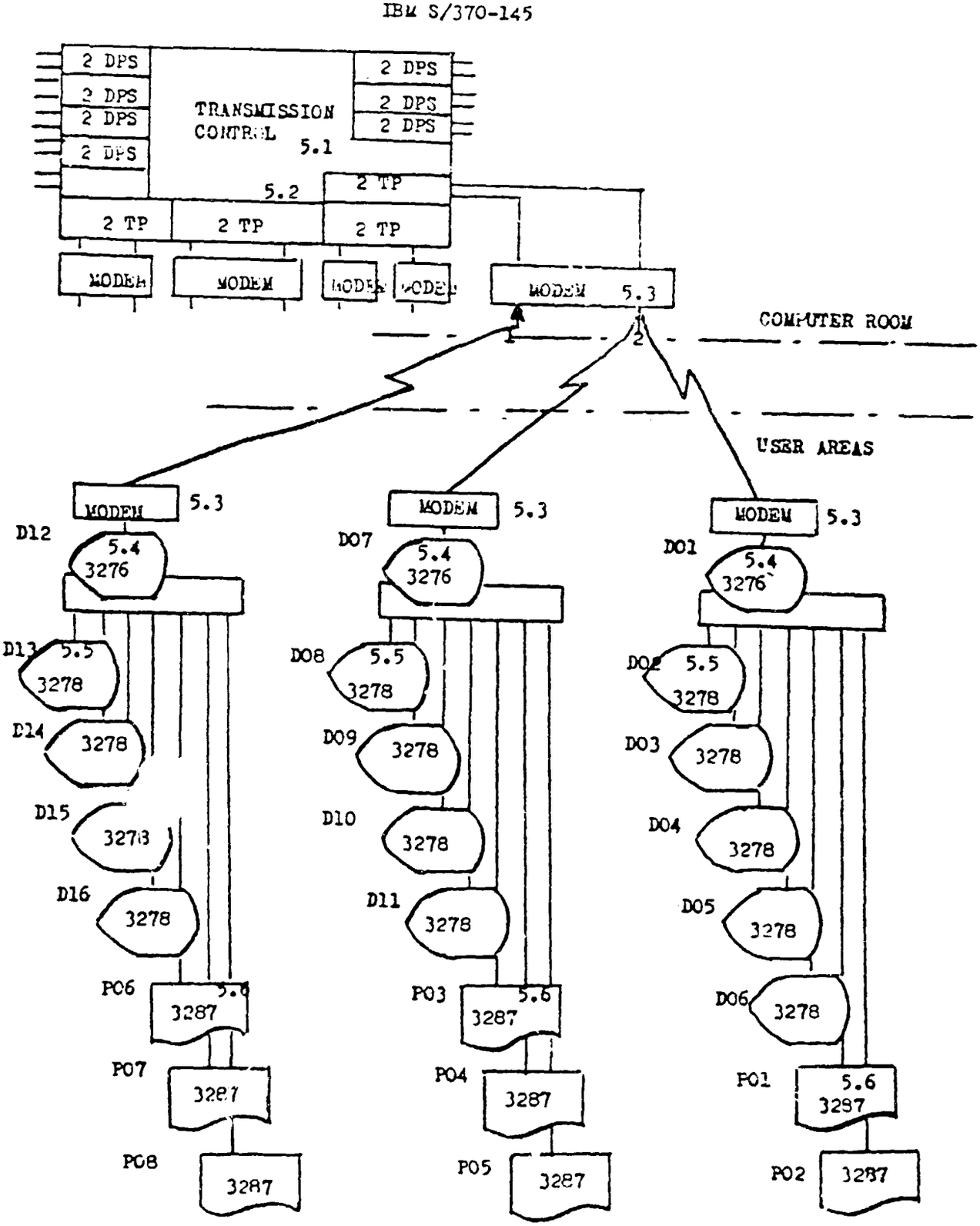


EXHIBIT 4 SYSTEM TERMINAL NETWORK

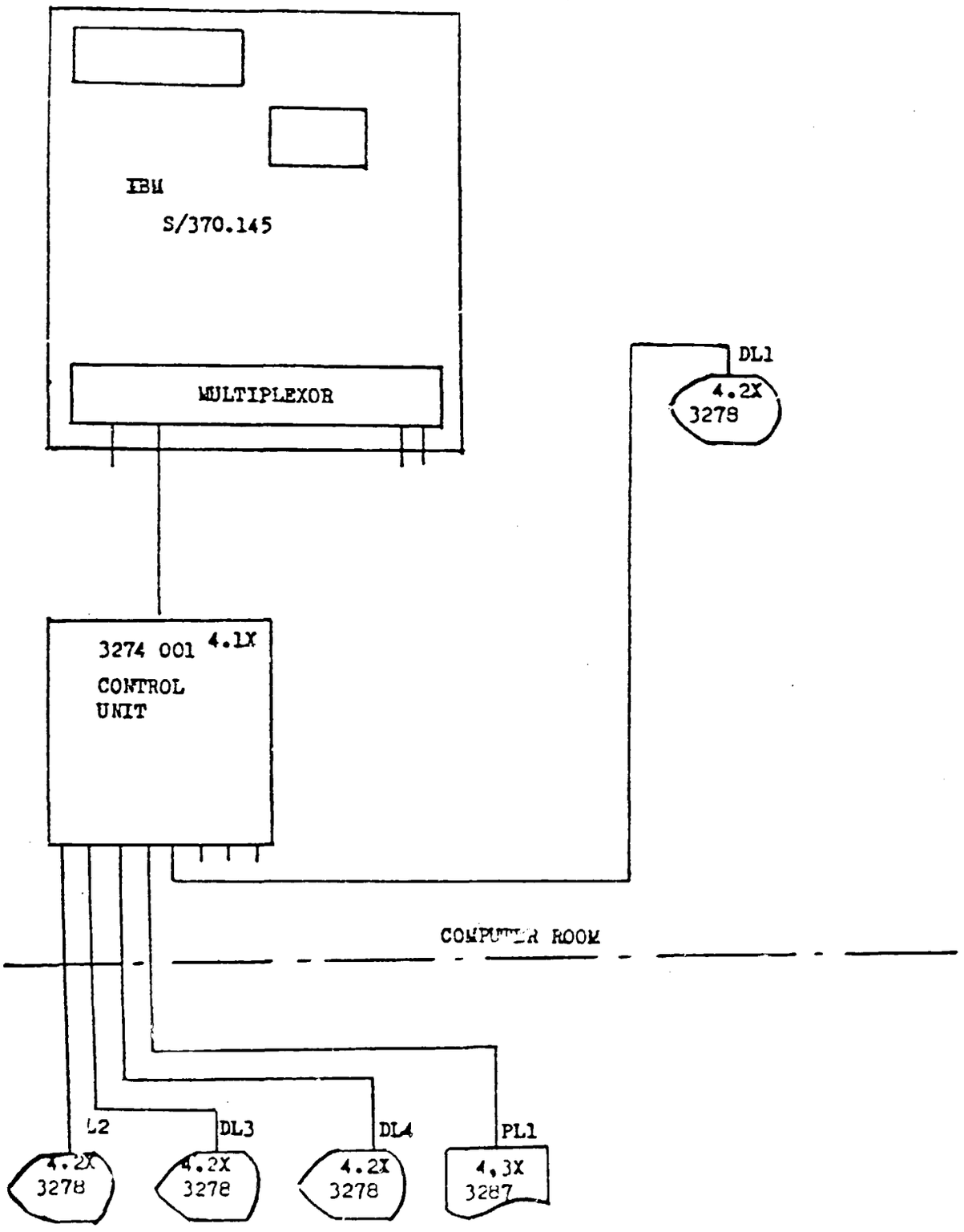


EXHIBIT 9 LOCAL TERMINAL CLUSTER

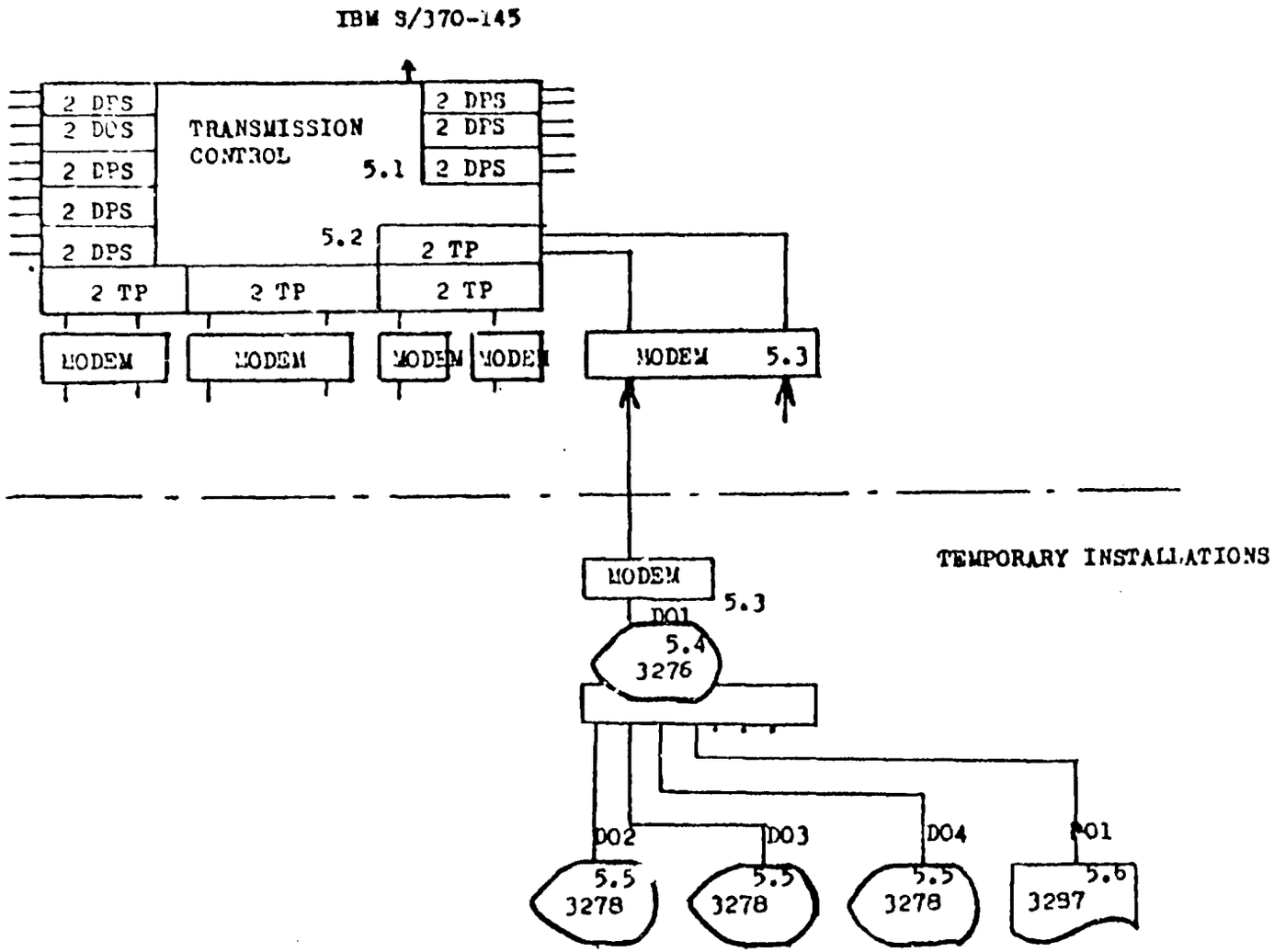


EXHIBIT 6 SYSTEM DEVELOPMENT TERMINAL CLUSTER

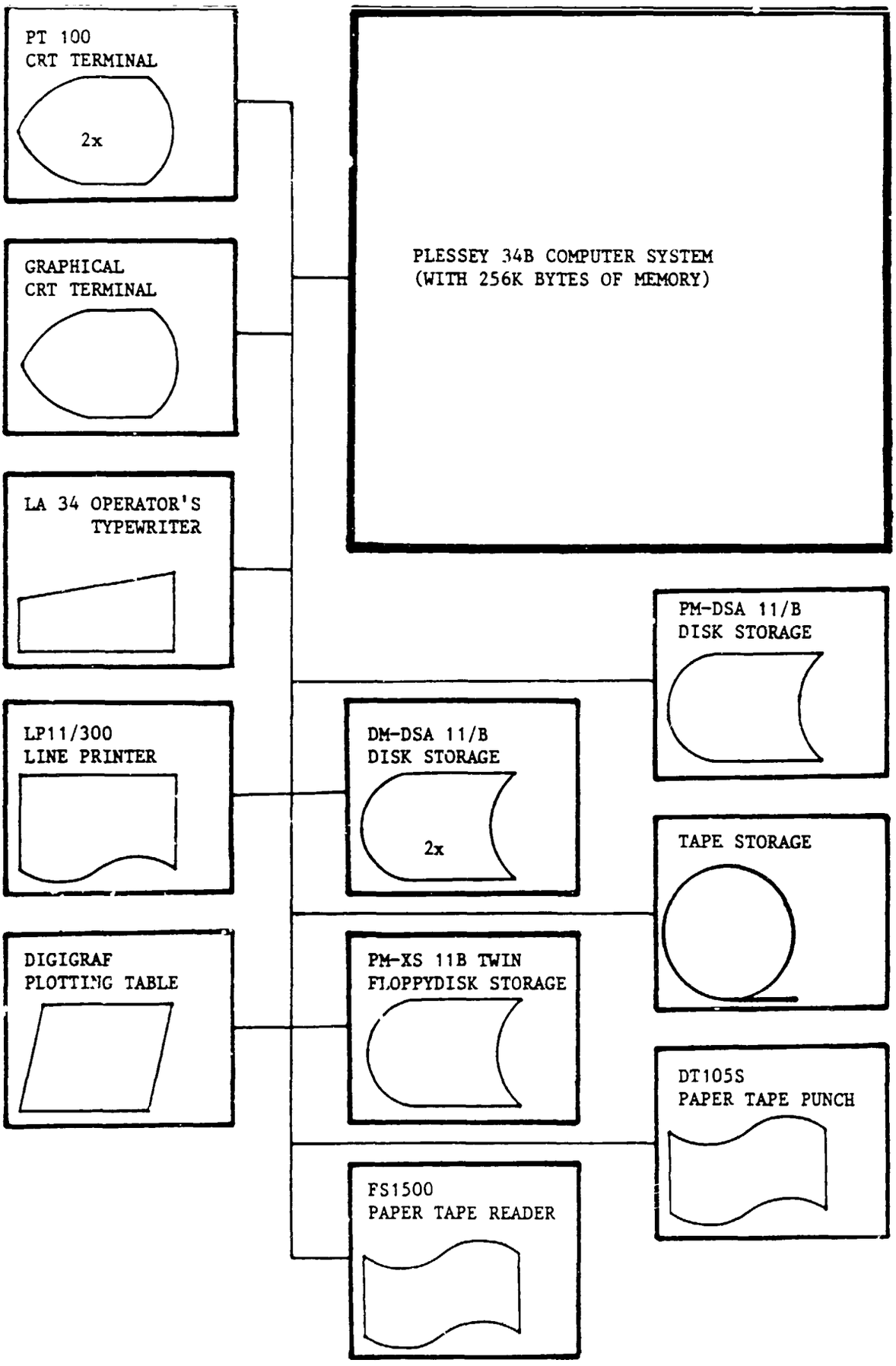


EXHIBIT 7 MINICOMPUTER LABORATORY HARDWARE CONFIGURATION

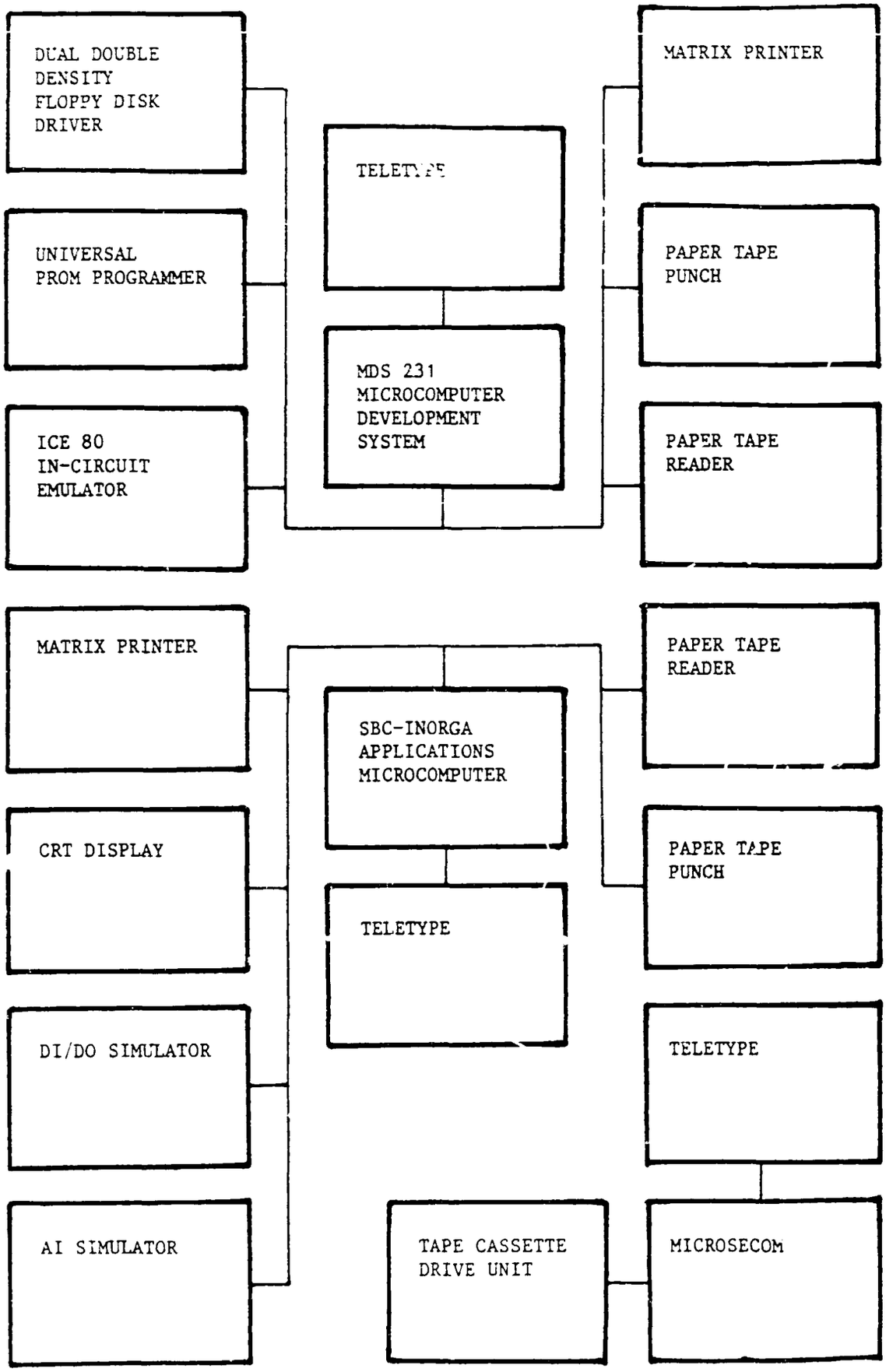


EXHIBIT 8 MICROCOMPUTER LABORATORY HARDWARE CONFIGURATION

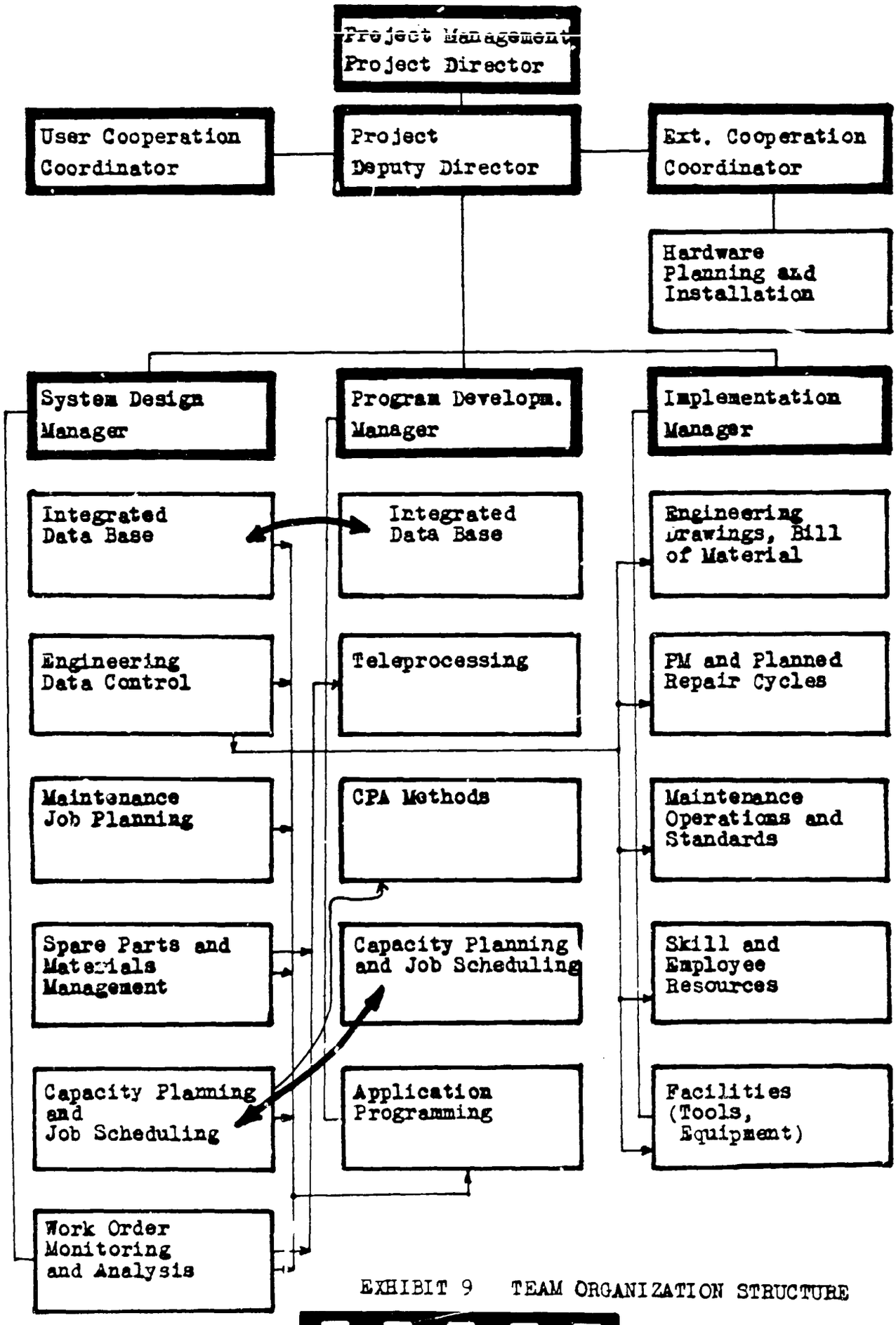


EXHIBIT 9 TEAM ORGANIZATION STRUCTURE