3

The Generic Duties of a CIM System and Their Expression via the Hierarchical Form of the Reference Model (Scheduling and Control Hierarchy View) of the System

THE GENERIC TASKS OF A PLANT-WIDE COMPUTER CONTROL SYSTEM

Overall automatic control of any large modern industrial plant regardless of the industry concerned involves each of the requirements listed in Table 3-I.

Thus the automation of any such industrial plant becomes the managing of the plants' information systems to assure that the necessary information is collected and used wherever it can enhance the plants' operation - true information systems technology in its broadest sense.

Another major factor should also be called to our attention here. It has been repeatedly shown that one of the major benefits of the use of digital computer control systems in the automation of industrial plants has been in the role of a *control systems enforcer.* In this mode, one of the control computer's main tasks is to continually assure that the control system equipment is actually carrying out the job that it was designed to do in keeping the units of the plant production system operating at some best (near optimal) level. That is, to be sure that in the continuous process plant, for instance, the controllers have not been set on manual, that the optimal set points are being maintained, etc. Likewise, it is the task of dynamic control to assure that the plant's production schedule is carried out, i.e., to *enforce* the task set by the production scheduling function.

Often the tasks carried out by these control systems have been ones which a *skilled* and *attentive* operator could have readily done himself. The difference is the degree of attentiveness to the task at hand which can be achieved over the long run.

As stated earlier, all of this must be factored into the design and operation of the control system which will operate the plant, including the requirements for maximum productivity and minimum raw material and energy usage. As the overall requirements, both energy and productivity based, become more complex, more sophisticated and capable control systems are necessary.

While the above tasking list is truly generic for any manufacturing plant - continuous or discrete - it is necessary to rearrange it in order to come up with a more compact set of tasks for further discussion.

TABLE 3-I

DUTIES (FUNCTIONAL REQUIREMENTS) OF ALL INTEGRATED INFORMATION AND AUTOMATION SYSTEMS A GENERIC LIST

1. AN EXTENSIVE SYSTEM FOR THE AUTOMATIC MONITORING OF A LARGE NUMBER OF DIFFERENT PLANT VARIABLES OPERATING OVER A VERY WIDE RANGE OF PROCESS OPERATIONS AND OF PROCESS DYNAMIC BEHAVIOR. SUCH MONITORING WILL DETECT AND COMPENSATE FOR CURRENT OR IMPENDING PLANT EMERGENCIES OR PRODUCTION PROBLEMS.

2. THE DEVELOPMENT OF A LARGE NUMBER OF QUITE COMPLEX, USUALLY NONLINEAR, RELATIONSHIPS FOR THE TRANSLATION OF SOME OF THE ABOVE PLANT VARIABLE VALUES INTO CONTROL CORRECTION COMMANDS.

3. THE TRANSMISSION OF THESE CONTROL CORRECTION COMMANDS TO ANOTHER VERY LARGE SET OF WIDELY SCATTERED ACTUATION MECHANISMS OF VARIOUS TYPES.

4. IMPROVEMENT OF ALL ASPECTS OF THE MANUFACTURING OPERATIONS OF THE PLANT BY GUIDING THEM TOWARD LIKELY OPTIMA OF THE APPROPRIATE ECONOMIC OR OPERATIONAL CRITERIA. RESULTS MAY BE APPLIED TO THE CONTROL CORRECTION COMMANDS OF ITEM 2 ABOVE AND/OR TO THE PLANT SCHEDULING FUNCTIONS OF ITEM 8 BELOW.

5. RECONFIGURATION OF THE PLANT PRODUCTION SYSTEM AND/OR OF THE CONTROL SYSTEM AS NECESSARY AND POSSIBLE TO ASSURE THE APPLICABLE PRODUCTION AND/OR CONTROL SYSTEM FOR THE MANUFACTURING SITUATION AT HAND.

6. KEEPING PLANT PERSONNEL, BOTH OPERATING AND MANAGEMENT, AWARE OF THE CURRENT STATUS OF THE PLANT AND OF EACH OF ITS PROCESSES AND THEIR PRODUCTS INCLUDING SUGGESTION FOR ALTERNATE ACTIONS WHERE NECESSARY.

7. REDUCTION OF PLANT OPERATIONAL AND PRODUCTION DATA AND PRODUCT QUALITY DATA TO FORM A HISTORICAL DATABASE FOR REFERENCE BY PLANT ENGINEERING, OTHER STAFF FUNCTIONS AND MARKETING.

8. ADJUSTING THE PLANT'S PRODUCTION SCHEDULE AND PRODUCT MIX TO MATCH ITS CUSTOMER'S NEEDS, AS EXPRESSED BY THE NEW ORDER STREAM BEING CONTINUALLY RECEIVED, WHILE MAINTAINING A HIGH PLANT PRODUCTIVITY AND THE LOWEST PRACTICAL PRODUCTION COSTS. THIS FUNCTION MUST ALSO PROVIDE FOR APPROPRIATE PLANT PREVENTIVE OR CORRECTIVE MAINTENANCE FUNCTIONS.

9. DETERMINATION OF AND PROVISION FOR APPROPRIATE INVENTORY AND USE LEVELS FOR RAW MATERIALS, ENERGY, SPARES, GOODS IN PROCESS AND PRODUCTS TO MAINTAIN DESIRED PRODUCTION AND ECONOMICS FOR THE PLANT.

10. ASSURING THE OVERALL AVAILABILITY OF THE CONTROL SYSTEM FOR CARRYING OUT ITS ASSIGNED TASKS THROUGH THE APPROPRIATE COMBINATION OF FAULT DETECTION AND FAULT TOLERANCE, REDUNDANCY, AND FAIL-SAFE TECHNIQUES.

11. MAINTAIN INTERFACES WITH THE EXTERNAL ENTITIES WHICH INTERACT WITH THE PLANT PRODUCTION SYSTEM SUCH AS CORPORATE MANAGEMENT; MARKETING; ACCOUNTING; CORPORATE RESEARCH, DEVELOPMENT AND ENGINEERING; EXTERNAL TRANSPORTATION; SUPPLIERS AND VENDORS; PURCHASING; CUSTOMERS; AND CONTRACTORS.

Therefore, what is needed is an overall system for any manufacturing plant which has the capabilities shown in Table 3-II.

In view of Item 2 of Table 3-II, Table 3-III presents some observations of the differences in process improvement technologies (i.e., near optimization) for continuous versus discrete optimization.

Because of the ever-widening scope of authority of each of the first three requirements in turn, they effectively become the distinct and separate levels of a superimposed control structure, one on top of the other. Also in view of the amount of information which must be passed back and forth among the above four "tasks" of control, a distributed computational capability organized in a hierarchical fashion would seem to be the logical structure for the required control system. This must be true of any plant regardless of the industry involved.

As just noted, a hierarchical arrangement of the elements of a distributed, computer-based control system seems an ideal arrangement for carrying out the automation of the industrial plant just described. Figures 3-1 and 3-2 lay out one possible form of this distributed, hierarchical computer control system for overall plant automation. Note that Figure 3-1 uses the nomenclature common to the continuous process industries while Figure 3-2 presents the computer integrated manufacturing system or CIMS commonly used in the discrete manufacturing industries to represent the hierarchy. Note that the levels represented here are "functional" levels. Whether or not they represent actual physical hardware levels depends on how large and complex the actual manufacturing plant is. Nevertheless it is our thesis that the two diagrams of Figures 3-1 and 3-2 are exactly functionally equivalent.

Figures 3-1 and 3-2 represent the simplest situation - that of a company with only one manufacturing plant. The corresponding situation with a multiplant company is represented in Figure 3-3 in that an additional level is necessary to separate the company's distribution or assignment of orders to the various plants from the plant's own production scheduling activities. In addition, the company management functions of Level 4B are now transferred to a new Level 5B. With this simple discussion of potential expansion of the model, continuing discussion of the model in this document will concentrate, for ease of consideration, on the single plant company, i.e., Figures 3-1 and 3-2. The tasks carried out at Level 5B would be the same as those assigned here at Level 4B in Table 3-VI with suitable allowance for the wider horizon of interest of the management of the larger company.

TABLE 3-II

AN OVERALL PLANT AUTOMATION SYSTEM MUST PROVIDE

1. AN EFFECTIVE DYNAMIC CONTROL OF EACH OPERATING UNIT OF THE PLANT TO ASSURE THAT IT IS OPERATING AT ITS MAXIMUM EFFICIENCY OF PRODUCTION CAPABILITY, PRODUCT QUALITY AND/OR OF ENERGY AND MATERIALS UTILIZATION BASED UPON THE PRODUCTION LEVEL SET BY THE SCHEDULING AND SUPERVISORY FUNCTIONS LISTED BELOW. THIS THUS BECOMES THE *CONTROL ENFORCEMENT* COMPONENT OF THE SYSTEM. THIS CONTROL REACTS DIRECTLY TO COMPENSATE FOR ANY EMERGENCIES WHICH MAY OCCUR IN ITS OWN UNIT.

2. A SUPERVISORY AND COORDINATING SYSTEM WHICH DETERMINES AND SETS THE LOCAL PRODUCTION LEVEL OF ALL UNITS WORKING TOGETHER BETWEEN INVENTORY LOCATIONS IN ORDER TO CONTINUALLY IMPROVE (I.E., OPTIMIZE) THEIR OPERATION. THIS SYSTEM ASSURES THAT NO UNIT IS EXCEEDING THE GENERAL AREA LEVEL OF PRODUCTION AND THUS USING EXCESS RAW MATERIALS OR ENERGY. THIS SYSTEM ALSO RESPONDS TO THE EXISTENCE OF EMERGENCIES OR UPSETS IN ANY OF THE UNITS UNDER ITS CONTROL IN COOPERATION WITH THOSE UNITS' DYNAMIC CONTROL SYSTEMS TO SHUT DOWN OR SYSTEMATICALLY REDUCE THE OUTPUT IN THESE AND RELATED UNITS AS NECESSARY TO COMPENSATE FOR THE EMERGENCY. IN ADDITION, THIS SYSTEM IS RESPONSIBLE FOR THE EFFICIENT REDUCTION OF PLANT OPERATIONAL DATA FROM THE DYNAMIC CONTROL UNITS, DESCRIBED JUST ABOVE, TO ASSURE ITS AVAILABILITY FOR USE BY ANY PLANT ENTITY REQUIRING ACCESS TO IT AS WELL AS ITS USE FOR THE HISTORICAL DATABASE OF THE PLANT.

3. AN OVERALL PRODUCTION CONTROL SYSTEM CAPABLE OF CARRYING OUT

continued

Table 3-II continued

THE SCHEDULING FUNCTIONS FOR THE PLANT FROM CUSTOMER ORDERS OR MANAGEMENT DECISIONS SO AS TO PRODUCE THE REQUIRED PRODUCTS FOR THESE ORDERS AT THE BEST (NEAR OPTIMUM) COMBINATION OF CUSTOMER SERVICE AND OF THE USE OF TIME, ENERGY, INVENTORY, MANPOWER AND RAW MATERIALS SUITABLY EXPRESSED AS COST FUNCTIONS.

4. A METHOD OF ASSURING THE OVERALL RELIABILITY AND AVAILABILITY OF THE TOTAL CONTROL SYSTEM THROUGH FAULT DETECTION, FAULT TOLERANCE, REDUNDANCY, UNINTERRUPTIBLE POWER SUPPLIES, MAINTENANCE PLANNING, AND OTHER APPLICABLE TECHNIQUES BUILT INTO THE SYSTEM'S SPECIFICATION AND OPERATION.

TABLE 3-III

SOME NOTES REGARDING OPTIMIZATION (IMPROVEMENT) OF MANUFACTURING EFFICIENCY

IN DISCRETE MANUFACTURING OPTIMIZATION (IMPROVEMENT) IS GENERALLY CARRIED OUT IN SCHEDULING.

IN CONTINUOUS MANUFACTURING OPTIMIZATION (IMPROVEMENT) IS GENERALLY CARRIED OUT BOTH IN CONTROL AND SCHEDULING.

Figure 3-4 compares the model described here with that developed by ISO Working Group 1 (Reference Models Working Group) [38]. Note that Levels 1 and 6 of that model are omitted in the Purdue model for the reasons given on the figure. The remaining levels have been correspondingly renumbered. Figure 3-5 continues this analysis by showing the corresponding hierarchical computer system diagram with similar notation on the differences between the two models. Task definitions are essentially the same in both models at all levels. See also Figure 1-3.

As noted, the International Purdue Workshop Model has a narrower scope than the ISO Reference Model Committee's work for two major reasons:

1. The Shop Floor is not specifically included in the IPW model since it is strictly an Information Management and Control Model and because shop floor equipment can vary so widely between different industries. The ISO Committee's model is restricted to Discrete Products plants.

2. The Corporate Management tasks are considered innovative in the IPW study and are therefore considered External Entities since innovative procedures cannot be mathematically modelled with present technology.

Working Group 1 has been mandated by the International Standards Organization (ISO) to develop a CIM Reference Model. However, their scope of work at present calls only for using the resulting model as a means for helping develop needs for additional international standards to facilitate the field of CIM [38].

Working Group 1 has developed three separate views of the CIM Reference Model in their work. These are the model of Discrete Parts Manufacturing (DPM) reproduced here as Figure 1-3 (a modified data-flow or functional analysis view); a six level hierarchical control Factory Automation Model (FAM) for manufacturing activities reproduced here as Figure 3-5 (a modified scheduling and control view); and a Generic Production Activity Model (GPAM) which described a set of generic activities which occur at all levels of the hierarchy (a physics view and discussed here in Appendix III).

DISCRETE PARTS MANUFACTURING ENVIRONMENT (DPM)

As established by WG1 for their study, the scope of manufacturing automation was perceived to be all-inclusive, from customer order through delivery of the product. Twelve major activities have been identified as being a part of this scope.

1. Corporate Management
2. Finance
3. Marketing and Sales
4. Research, Development and Engineering

(Items 1–4: Considered External Influences in the Purdue Model)

5. Process Support Engineering
6. Procurement
7. Resources Management
8. Production Management
9. Shipping
10. Shop Floor Production
11. Waste Material Treatment
12. Maintenance Management

(Items 5–12: Included in the Purdue Model)

Figure 1-3 depicts the important relationships and interfaces among these activities. It provides an "environment" for Discrete Parts Manufacturing and forms the basis for the other models.

FACTORY AUTOMATION MODEL (FAM)

As just noted WG1 restricted its scope to those activities which are included in and directly related to Shop Floor Production (see Figure 1-3). A

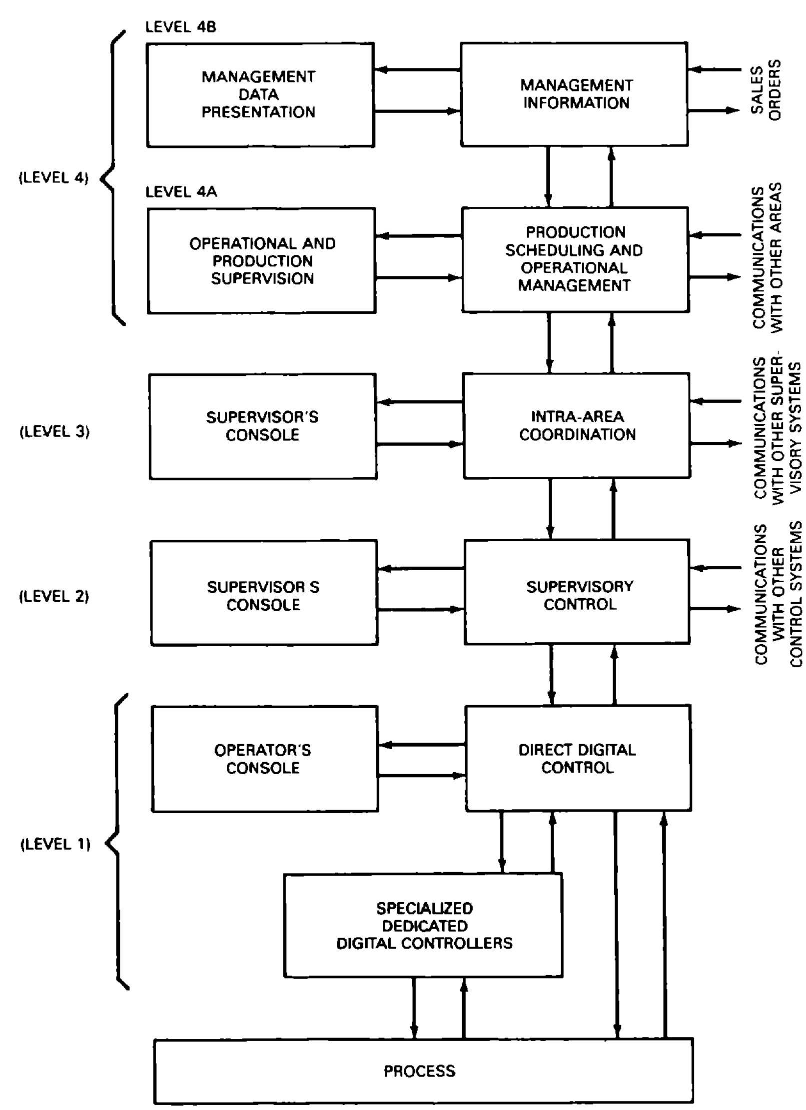

Figure 3-1 Assumed functional hierarchical computer control structure for an industrial plant (continuous process such as petrochemicals).

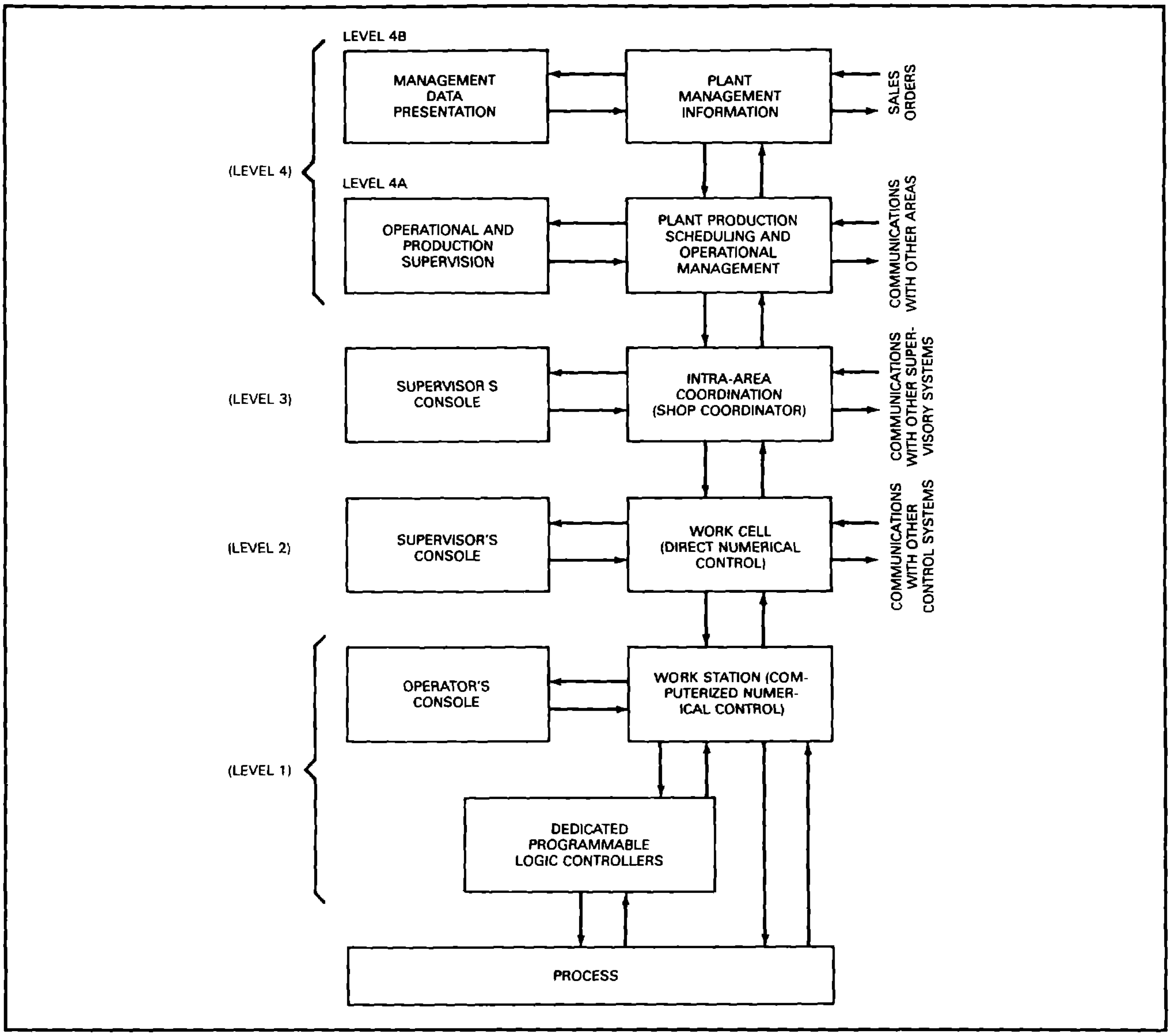

Figure 3-2 Assumed functional hierarchy computer system structure for a large manufacturing complex (Computer Integrated Manufacturing System (CIMS)).

six level hierarchical model was selected to represent those activities (see Figures 3-4 and 3-5). It is quite likely that specific applications may require more or fewer than six levels. But, six was deemed sufficient for the purposes of identifying where integration standards are required. The following table shows the name of each level and gives its major responsibility. More detail is shown in Figure 3-4.

LEVEL 6 ENTERPRISE — CORPORATE MANAGEMENT (EXTERNAL INFLUENCES)

LEVEL 5 FACILITY — PLANNING PRODUCTION

LEVEL 4 SECTION — MATERIAL/RESOURCE SUPERVISION

LEVEL 3 CELL — COORDINATE MULTIPLE MACHINES

LEVEL 2 STATION — COMMAND MACHINE SEQUENCES

LEVEL 1 EQUIPMENT — ACTIVATE SEQUENCES OF MOTION (PLANT MACHINERY AND EQUIPMENT)

These activities apply to manual operations, automated operations, or a mixture of the two at any level. Figure 3-5 shows a sample implementation of these six levels.

As noted above these two figures describe very well the Purdue Scheduling and Control View of their CIM Reference Model except for WG1 Levels 1 and 6 which are not included in the Purdue Model for the reasons noted just above.

In the context of large industrial plants or of a complete industrial company based in one location, the detailed tasks that would be carried out at each level of the hierarchy can be readily described. These tasks are easily subdivided into those related to production scheduling, control enforcement, systems coordination and reporting, and reliability assurance (Table 3-IV).

It is the Committee's contention that such lists can outline the tasks which must be carried out in any industrial plant, particularly at the upper levels of the hierarchy. Details of how these operations are actually carried out may vary drastically, particularly at the lowest levels, because of the nature of the actual process being controlled. We all recognize that a distillation column will never look like or respond like an automobile production line. But the operations themselves remain the same in concept, particularly at the upper levels of the hierarchy.

Thus it is our contention that despite the different nomenclature of Figures 3-1 and 3-2 that the major differences in the control systems involved is concentrated in the details of the dynamic control technologies used at Level 1 and the details of the mathematical models used for optimization at Level 2.

The differences are thus concentrated in the details of the control and operation of the individual production units (the application entities) of the factory. Commonality is in the support functional entities (computational services, communications, database technology, management structure, etc.). Sensing and communication techniques are exactly the same in both systems. The same optimization algorithms can be used. Computer systems technology and programming techniques should be the same and production scheduling technology should be identical to name only a few.

Thus the duties of the hierarchical computer system can be established as outlined in Table 3-IV and in Figure 3-6. Therefore Levels 1 and 2 will

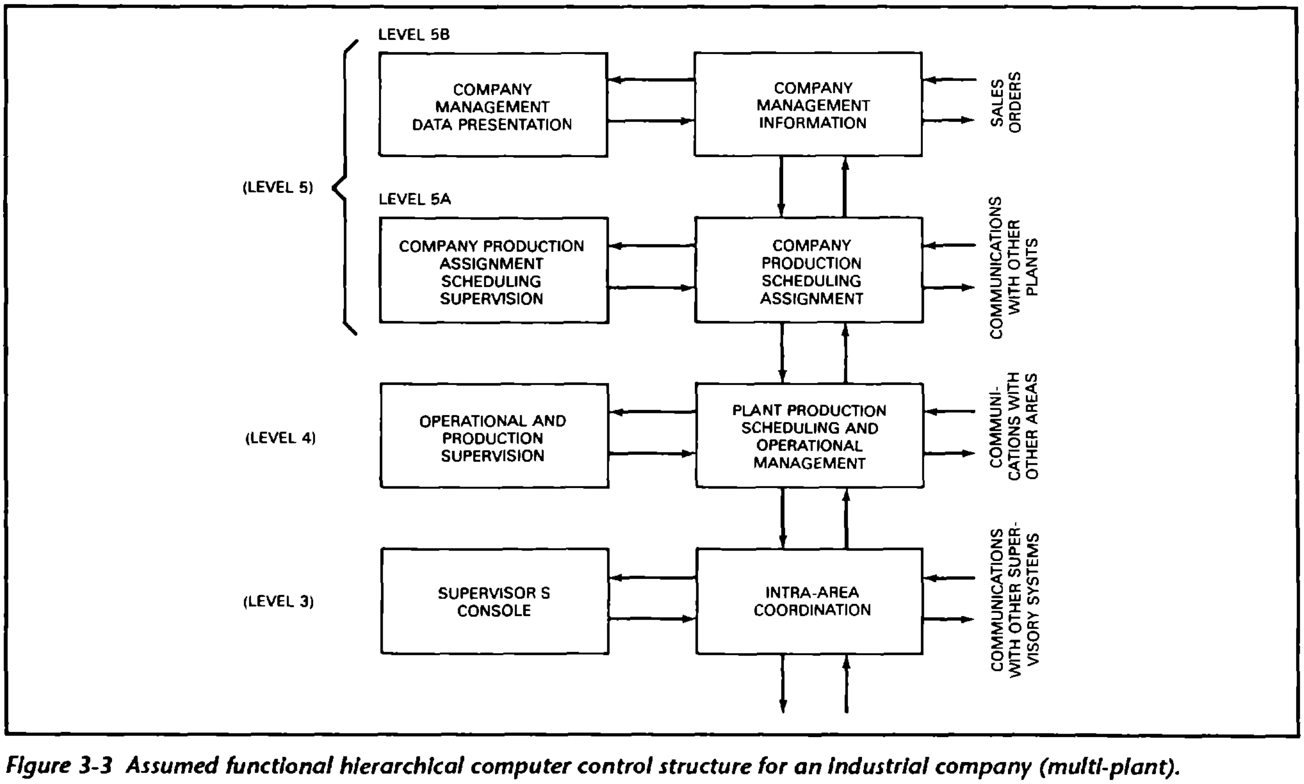

Figure 3-3 Assumed functional hierarchical computer control structure for an industrial company (multi-plant).

IPW LEVEL NOTATION	WG1 LEVEL	HIERARCHY	CONTROL	RESPONSIBILITY	BASIC FUNCTIONS	
NULL	6	ENTERPRISE	CORPORATE MANAGEMENT	Achieving the mission of the enterprise and managing the corporate	— CORPORATE MANAGEMENT — FINANCE — MARKETING & SALES — RESEARCH & DEVELOPMENT	CONSIDERED AN EXTERNAL ENTITY IN THE IPW WORK
4	5	FACILITY/ PLANT	PLANNING PRODUCTION	Implementation of the enterprise functions, and planning and scheduling the production	— PRODUCT DESIGN & PRODUCTION ENGINEERING — PRODUCTION MANAGEMENT (Upper Level) — PROCUREMENT (Upper Level) — RESOURCES MANAGEMENT (Upper Level) — MAINTENANCE MANAGEMENT (Upper Level)	
3	4	SECTION/ AREA	ALLOCATING AND SUPERVISING MATERIALS & RESOURCES	Coordinate the production and supporting the jobs and obtaining and allocating resources to the jobs	— PRODUCTION MANAGEMENT (Lower Level) — PROCUREMENT (Lower Level) — RESOURCES MANAGEMENT (Lower Level) — MAINTENANCE MANAGEMENT (Lower Level) — SHIPPING — WASTE MATERIAL TREATMENT	
2	3	CELL	COORDINATE MULTIPLE MACHINES AND OPERATIONS	Sequencing and supervising the jobs at the shop floor, and supervising various supporting services	— SHOP FLOOR PRODUCTION (Cell Level)	
1	2	STATION	COMMAND MACHINE SEQUENCES AND MOTION	Directing and coordinating the activity of the shop floor equipments	— SHOP FLOOR PRODUCTION (Station Level)	
0	1	EQUIPMENT	ACTIVATE SEQUENCES AND MOTION	Realization of commands to the shop floor equipments	— SHOP FLOOR PRODUCTION (Equipment Level)	NOT INCLUDED BECAUSE OF WIDE DIFFERENCES OF EQUIPMENT AND FUNCTIONS BETWEEN DIFFERENT INDUSTRIES

Figure 3-4 Factory automation model.

concentrate on performing Task II of Table 3-IV, Levels 3 and 4 will carry out Task I and all will be involved in assuring the implementation of Task III and the integrity of Task IV, overall reliability and availability.

Possibilities of major reduction in the costs, development manpower effort, and time required to produce an integrated industrial control system then devolves upon the factors listed in Table 3-V [81].

TASKS OF EACH OF THE LEVELS OF THE HIERARCHY

In the context of any large industrial plant, or of a complete industrial company based in one location, the tasks that would be carried out at each level of the hierarchy are as described in Tables 3-VI to 3-X. Note that these tasks are subdivided within each table into those related to production scheduling, control enforcement, systems coordination and reporting, and reliability assurance (Table 3-IV). As was mentioned above, these tables outline the tasks which must be carried out in any industrial plant, particularly at the upper levels of the hierarchy.

Figures 3-7 to 3-10 present another form of the same information as presented in the tables listed just above to show the relationships and the interactions of the tasks given.

Figures 3-11 to 3-16 show the application of the Scheduling and Hierarchy View to a variety of industries showing also that the computer control system discussed here is pyramidal as well as hierarchical. Figure 3-16 is an entirely different appearing diagram as originally developed by the Cincinnati-Milacron Company. However with the current CIM hierarchy levels imposed it can be readily seen that this diagram converts directly to the others.

Figures 3-11 to 3-16 also bring out an important aspect of this model in relation to those proposed by some other developers, that is, inventories and associated material handling equipments in relation to the manufacturing processes themselves are treated just like any other process. Thus they are considered to have process control inputs and outputs and their dynamic behavior can be modelled mathematically in order to develop the appropriate overall control system for the functions served by the inventory and its associated material handling equipment.

TABLE 3-IV

SUMMARY OF DUTIES OF CONTROL COMPUTER SYSTEMS

I. PRODUCTION SCHEDULING

II. CONTROL ENFORCEMENT

III. PLANT COORDINATION AND OPERATIONAL DATA REPORTING

IV. SYSTEM RELIABILITY AND AVAILABILITY ASSURANCE

ITEM I OF THE ABOVE LIST (PRODUCTION SCHEDULING) CORRESPONDS TO ITEM 3 OF THE LIST OF TABLE 3-II.

ITEM II OF THE ABOVE LIST CORRESPONDS TO MUCH OF ITEMS 1 AND 2 OF THE LIST OF TABLE 3-II.

ITEMS III AND IV OF THE ABOVE LIST REQUIRE THE COOPERATIVE OPERATION OF ALL ITEMS OF THE LIST OF TABLE 3-II. THE PLANT COORDINATION PART COMPRISES THE DETAILED INTERPRETATION AND EXPANSION OF THE OVERALL PRODUCTION SCHEDULE OF ITEM 3 OF TABLE 3-II.

TABLE 3-V

POTENTIAL FACTORS FOR FACILITATING INTEGRATED CONTROL SYSTEM DEVELOPMENT AND USE

1. POTENTIAL COMMONALITY OF CONTROL SYSTEM STRUCTURES IN TERMS OF THE:

   A. COMPUTER SYSTEMS,

   B. COMMUNICATIONS SYSTEM,

   C. DATABASE ORGANIZATION

   D. RELATIONSHIP TO PLANT MANAGEMENT AND OPERATIONAL STRUCTURE (PERSONNEL).

POTENTIAL FACTORS FOR FACILITATING INTEGRATED CONTROL SYSTEM DEVELOPMENT AND USE (CONT.)

2. COMMONALITY OF THE TECHNIQUES OF APPLICATION OF:

   A. SOFTWARE ENGINEERING AND PROGRAMMING,

   B. COMMUNICATIONS,

   C. DATABASE MANAGEMENT,

   D. CONTROL SYSTEMS ENGINEERING,

   E. PRODUCTION SCHEDULING,

   F. OPERATIONS RESEARCH AND OPTIMIZATION.

TABLE 3-VI

REQUIRED TASKS OF THE INTRA COMPANY COMMUNICATIONS CONTROL SYSTEM (LEVEL 4B OF FIGURE 3-1)

III SYSTEM COORDINATION AND REPORTING

1. MAINTAIN INTERFACES WITH

   (A) PLANT AND COMPANY MANAGEMENT,

   (B) SALES AND SHIPPING PERSONNEL,

   (C) ACCOUNTING, PERSONNEL AND PURCHASING DEPARTMENTS,

   (D) PRODUCTION SCHEDULING LEVEL (LEVEL 4A).

2. SUPPLY PRODUCTION AND STATUS INFORMATION AS NEEDED TO

continued

Table 3-VI continued

(A) PLANT AND COMPANY MANAGEMENT.

(B) SALES AND SHIPPING PERSONNEL.

(C) ACCOUNTING, PERSONNEL AND PURCHASING DEPARTMENTS

(D) THIS INFORMATION WILL BE SUPPLIED IN THE FORM OF

(1) REGULAR PRODUCTION AND STATUS REPORTS

(2) ON-LINE INQUIRIES

3. SUPPLY ORDER STATUS INFORMATION AS NEEDED TO SALES PERSONNEL.

IV. RELIABILITY ASSURANCE

4. PERFORM SELF CHECK AND DIAGNOSTIC CHECKS ON ITSELF.

NOTES:

1. THERE ARE NO PRODUCTION SCHEDULING OR CONTROL ACTIONS REQUIRED AT THIS LEVEL. THIS LEVEL IS SOLELY FOR USE AS AN UPPER MANAGEMENT AND STAFF LEVEL INTERFACE.

2. ROMAN NUMBER SUBDIVISIONS OF TABLES 3-VI TO 3-X CORRESPOND TO THE SAME HEADINGS IN TABLE 3-IV.

TABLE 3-VII

DUTIES OF THE PRODUCTION SCHEDULING AND OPERATIONAL MANAGEMENT LEVEL (LEVEL 4A)

I. PRODUCTION SCHEDULING

1. ESTABLISH BASIC PRODUCTION SCHEDULE.

2. MODIFY THE PRODUCTION SCHEDULE FOR ALL UNITS PER ORDER STREAM RECEIVED, ENERGY CONSTRAINTS, POWER DEMAND LEVELS, AND MAINTENANCE REQUIREMENTS.

3. IN COORDINATION WITH REQUIRED PRODUCTION SCHEDULE DEVELOP OPTIMUM PREVENTIVE MAINTENANCE AND PRODUCTION UNIT RENOVATION SCHEDULE.

4. DETERMINE THE OPTIMUM INVENTORY LEVELS OF RAW MATERIALS, ENERGY SOURCES, SPARE PARTS, ETC., AND OF GOODS IN PROCESS AT EACH STORAGE POINT. THE CRITERIA TO BE USED WILL BE THE TRADE-OFF BETWEEN CUSTOMER SERVICE (I.E., SHORT DELIVERY TIME) VERSUS THE CAPITAL COST OF THE INVENTORY ITSELF, AS WELL AS THE TRADE-OFFS IN OPERATING COSTS VERSUS COSTS OF CARRYING THE INVENTORY LEVEL. THIS FUNCTION WILL ALSO INCLUDE THE NECESSARY MATERIAL REQUIREMENTS PLANNING (MRP) AND SPARE PARTS PROCUREMENT TO SATISFY THE PRODUCTION SCHEDULE PLANNED. (THIS IS AN OFF-LINE FUNCTION.)

5. MODIFY PRODUCTION SCHEDULE AS NECESSARY WHENEVER MAJOR PRODUCTION INTERRUPTIONS OCCUR IN DOWNSTREAM UNITS, WHERE SUCH INTERRUPTIONS WILL AFFECT PRIOR OR SUCCEEDING UNITS.

III. PLANT COORDINATION AND OPERATIONAL DATA REPORTING

6. COLLECT AND MAINTAIN RAW MATERIAL AND SPARE PARTS USE AND AVAILABILITY INVENTORY AND PROVIDE DATA FOR PURCHASING FOR RAW MATERIAL AND SPARE PARTS ORDER ENTRY AND FOR TRANSFER TO ACCOUNTING.

7. COLLECT AND MAINTAIN OVERALL ENERGY USE AND AVAILABILITY INVENTORY AND PROVIDE DATA FOR PURCHASING FOR ENERGY SOURCE ORDER ENTRY AND FOR TRANSFER TO ACCOUNTING.

continued

Table 3-VII continued

8. COLLECT AND MAINTAIN OVERALL GOODS IN PROCESS AND PRODUCTION INVENTORY FILES.

9. COLLECT AND MAINTAIN THE QUALITY CONTROL FILE.

10. COLLECT AND MAINTAIN MACHINERY AND EQUIPMENT USE AND LIFE HISTORY FILES NECESSARY FOR PREVENTIVE AND PREDICTIVE MAINTENANCE PLANNING.

11. COLLECT AND MAINTAIN MANPOWER USE DATA FOR TRANSMITTAL TO PERSONNEL AND ACCOUNTING DEPARTMENTS.

12. MAINTAIN INTERFACES WITH MANAGEMENT INTERFACE LEVEL FUNCTION AND WITH AREA LEVEL SYSTEMS.

IV. RELIABILITY ASSURANCE

13. RUN SELF-CHECK AND DIAGNOSTIC ROUTINES ON SELF AND LOWER LEVEL MACHINES

NOTE:

THERE ARE NO CONTROL FUNCTIONS AS SUCH REQUIRED AT THIS LEVEL. THIS LEVEL IS FOR THE PRODUCTION SCHEDULING AND OVERALL PLANT DATA FUNCTIONS.

TABLE 3-VIII

DUTIES OF THE AREA LEVEL (LEVEL 3)

I. PRODUCTION SCHEDULING

1. ESTABLISH THE IMMEDIATE PRODUCTION SCHEDULE FOR ITS OWN AREA INCLUDING MAINNTENANCE, TRANSPORTATION AND OTHER PRODUCTION RELATED NEEDS.

2. LOCALLY OPTIMIZE THE COSTS FOR ITS INDIVIDUAL PRODUCTION AREA WHILE CARRYING OUT THE PRODUCTION SCHEDULE ESTABLISHED BY THE PRODUCTION CONTROL COMPUTER SYSTEM (LEVEL 4A) (I.E., MINIMIZE ENERGY USAGE OR MAXIMIZE PRODUCTION FOR EXAMPLE)

3. ALONG WITH LEVEL 4A MODIFY PRODUCTION SCHEDULES TO COMPENSATE FOR PLANT PRODUCTION INTERRUPTIONS WHICH MAY OCCUR IN ITS AREA OF RESPONSIBILITY.

III. SYSTEM COORDINATION AND OPERATIONAL DATA REPORTING

4. MAKE AREA PRODUCTION REPORTS INCLUDING VARIABLE MANUFACTURING COSTS

5. USE AND MAINTAIN AREA PRACTICE FILES

6. COLLECT AND MAINTAIN AREA DATA QUEUES FOR PRODUCTION, INVENTORY, AND MANPOWER, RAW MATERIALS, SPARE PARTS AND ENERGY USAGE

7. MAINTAIN COMMUNICATIONS WITH HIGHER AND LOWER LEVELS OF THE HIERARCHY

8. OPERATIONS DATA COLLECTION & OFF LINE ANALYSIS AS REQUIRED BY ENGINEERING FUNCTIONS INCLUDING STATISTICAL QUALITY ANALYSIS AND CONTROL FUNCTIONS

9. SERVICE THE MAN/MACHINE INTERFACE FOR THE AREA

10. CARRY OUT NEEDED PERSONNEL FUNCTIONS SUCH AS:

   (A) WORK PERIOD STATISTICS (TIME, TASK, ETC.)

   (B) VACATION SCHEDULE

   (C) WORK FORCE SCHEDULES

   (D) UNION LINE OF PROGRESSION

   (E) IN-HOUSE TRAINING AND PERSONNEL QUALIFICATION

continued

Table 3-VIII continued

IV. RELIABILITY ASSURANCE

11. DIAGNOSTICS OF SELF AND LOWER LEVEL FUNCTIONS

NOTE:

NO CONTROL ACTIONS ARE REQUIRED HERE. THIS LEVEL HANDLES DETAILED PRODUCTION SCHEDULING AND AREA COORDINATION FOR THE MAJOR PLANT SUBDIVISIONS.

TABLE 3-IX

DUTIES OF THE SUPERVISORY LEVEL (LEVEL 2)

II. CONTROL ENFORCEMENT

1. RESPOND TO ANY EMERGENCY CONDITION WHICH MAY EXIST IN ITS REGION OF PLANT COGNIZANCE

2. OPTIMIZE THE OPERATION OF UNITS UNDER ITS CONTROL WITHIN LIMITS OF ESTABLISHED PRODUCTION SCHEDULE. CARRY OUT ALL ESTABLISHED PROCESS OPERATIONAL SCHEMES OR OPERATING PRACTICES IN CONNECTION WITH THESE PROCESSES

III. SYSTEM COORDINATION AND OPERATIONAL DATA REPORTING

3. COLLECT AND MAINTAIN DATA QUEUES OF PRODUCTION, INVENTORY, AND RAW MATERIAL, SPARE PARTS AND ENERGY USAGE FOR THE UNITS UNDER ITS CONTROL

4. MAINTAIN COMMUNICATIONS WITH HIGHER AND LOWER LEVELS

5. SERVICE THE MAN/MACHINE INTERFACES FOR THE UNITS INVOLVED

IV. RELIABILITY ASSURANCE

6. PERFORM DIAGNOSTICS ON ITSELF AND LOWER LEVEL MACHINES

7. UPDATE ALL STANDBY SYSTEMS

NOTE:

THIS LEVEL AND THOSE BELOW IT CARRY OUT THE NECESSARY CONTROL AND OPTIMIZATION FUNCTIONS FOR THE INDIVIDUAL PRODUCTION UNITS TO ENFORCE THE PRODUCTION SCHEDULE SET BY LEVELS 4A AND 3.

TABLE 3-X

DUTIES OF THE CONTROL LEVEL (LEVEL 1)

II. CONTROL ENFORCEMENT

1. MAINTAIN DIRECT CONTROL OF THE PLANT UNITS UNDER ITS COGNIZANCE

2. DETECT AND RESPOND TO ANY EMERGENCY CONDITION WHICH MAY EXIST IN THESE PLANT UNITS

III. SYSTEM COORDINATION AND REPORTING

3. COLLECT INFORMATION ON UNIT PRODUCTION, RAW MATERIAL AND ENERGY USE AND TRANSMIT TO HIGHER LEVELS

4. SERVICE THE OPERATOR'S MAN/MACHINE INTERFACE

IV. RELIABILITY ASSURANCE

5. PERFORM DIAGNOSTICS ON ITSELF

6. UPDATE ANY STANDBY SYSTEMS

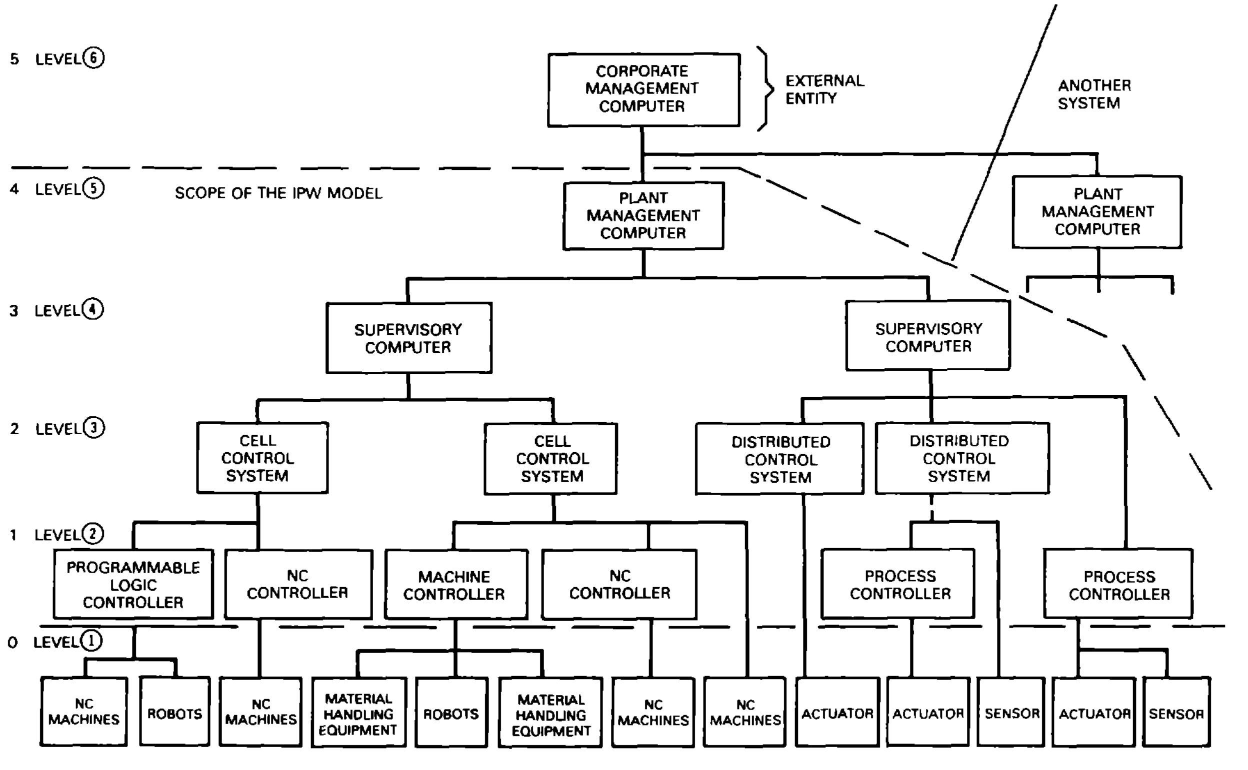

Figure 3-5 Example for system implementation of manufacturing.

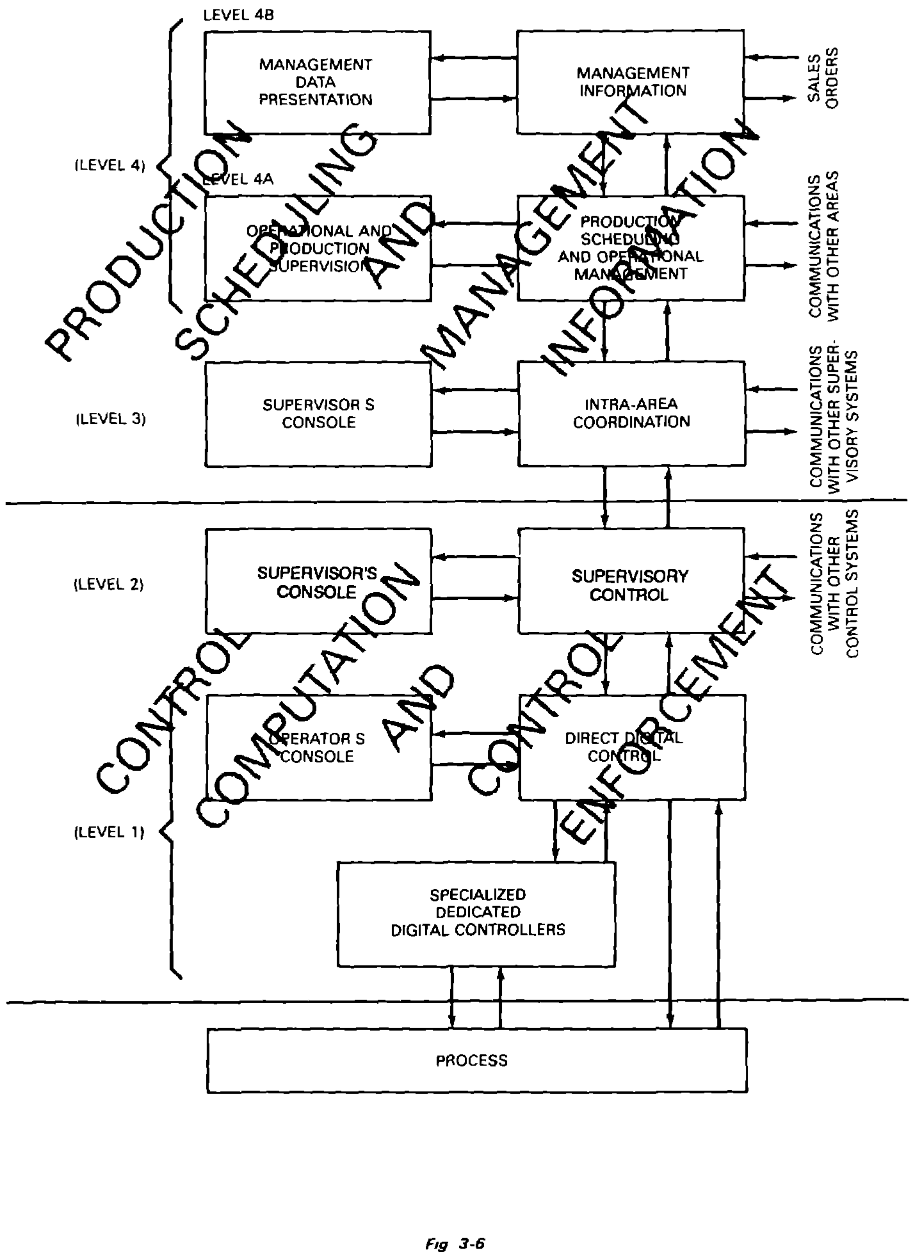

Figure 3-6 Definition of the real tasks of the hierarchical computer control system.

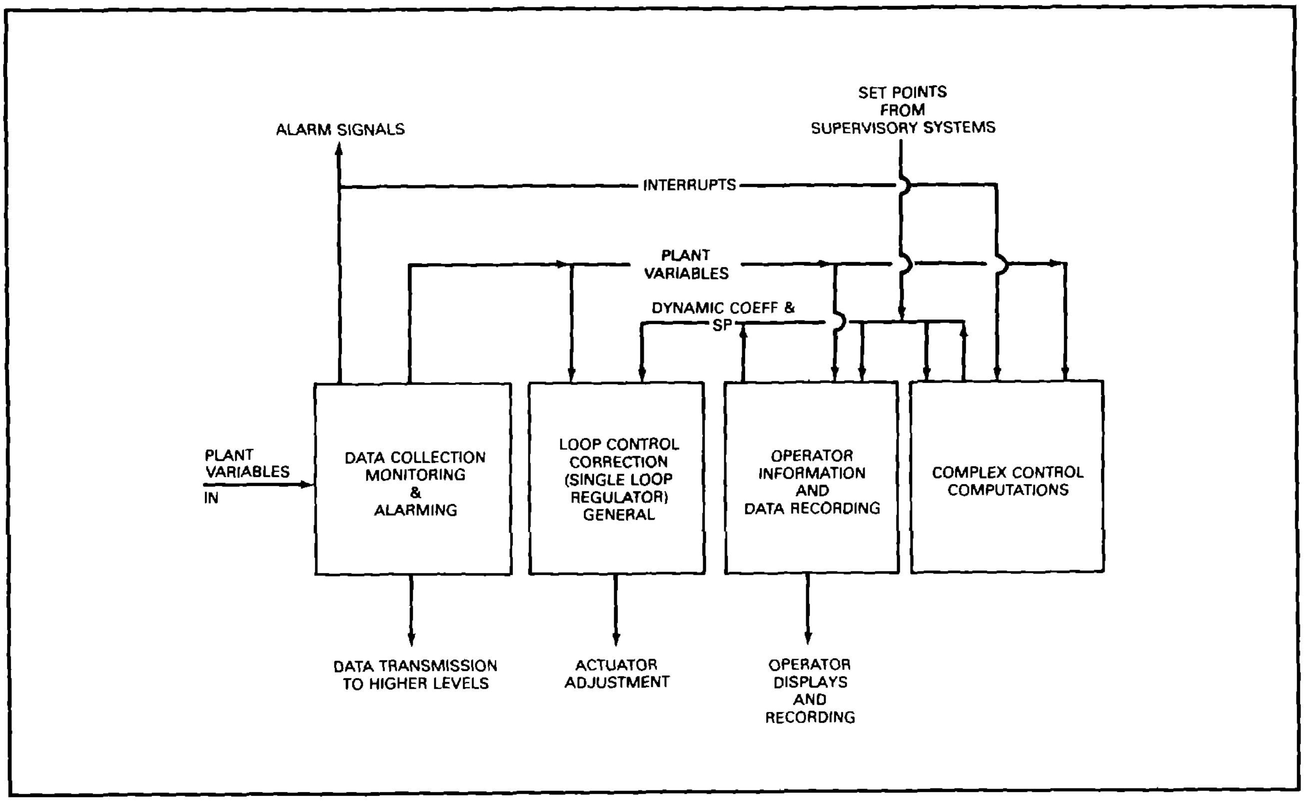

Figure 3-7 A block diagram of a generalized primary level (Level 1) control system.

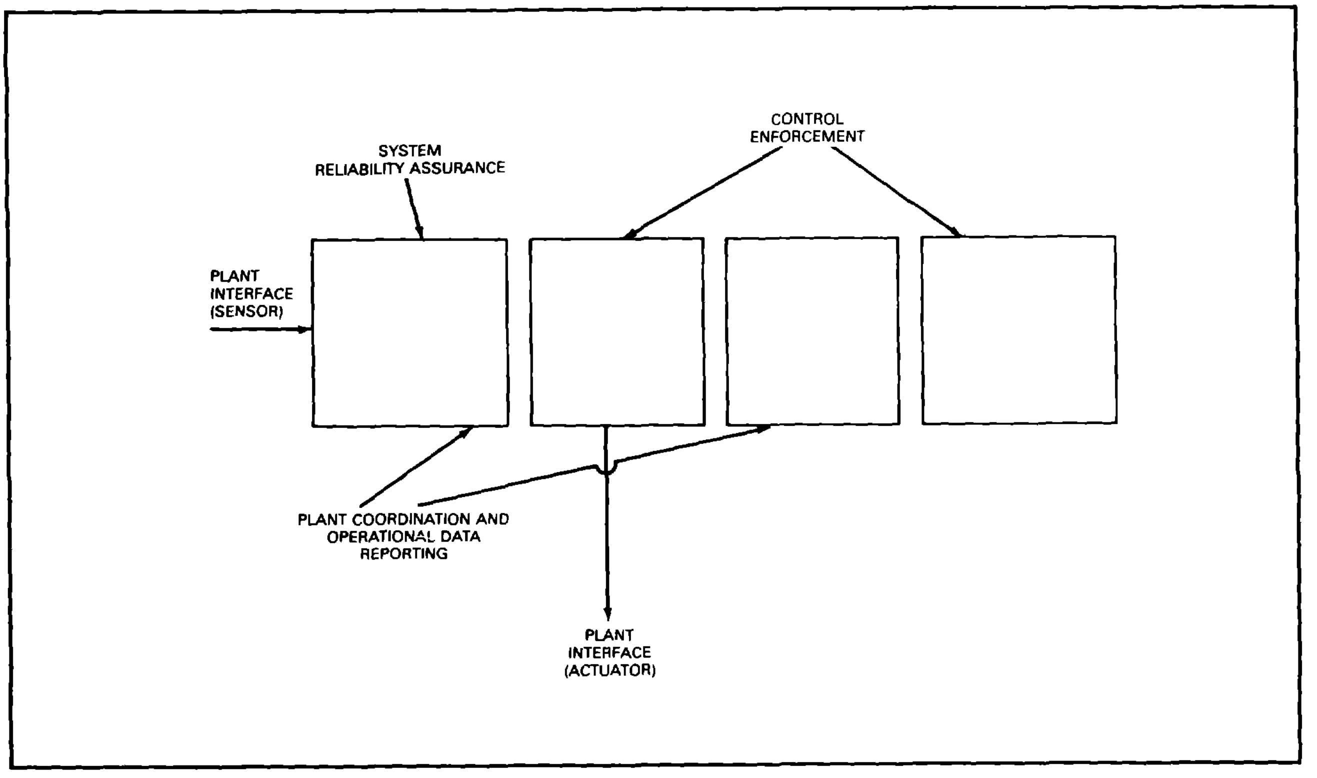

Figure 3-7A Explanation of the tasks of hierarchical Level 1 versus material of Tables 3-IV, 3-VI–3-X and Figure 3-6.

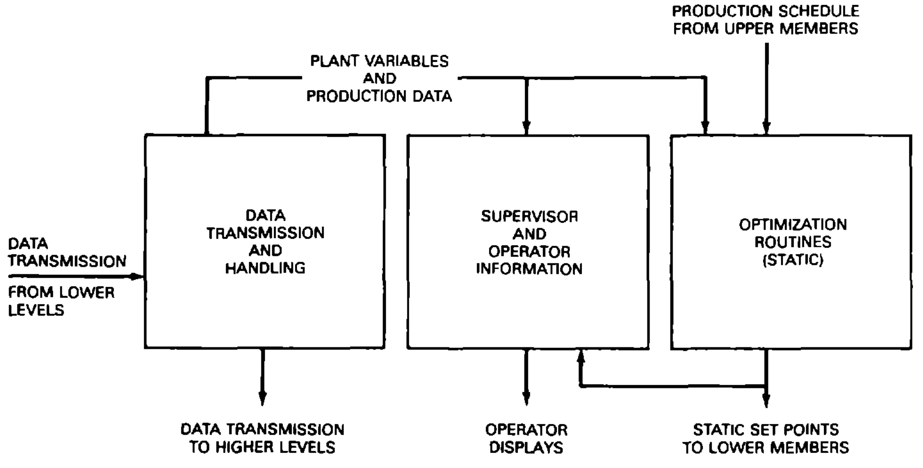

Figure 3-8 A block diagram of the supervisory control level (Level 2) of an overall proess control system.

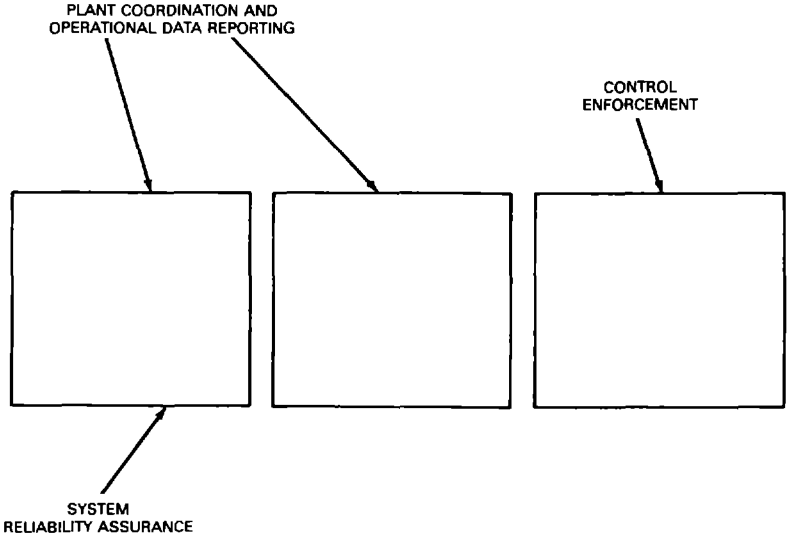

Figure 3-8A Explanation of the tasks of hierarchical level two versus material of Tables 3-IC, 3-VI–3-X and Figure 3-6.

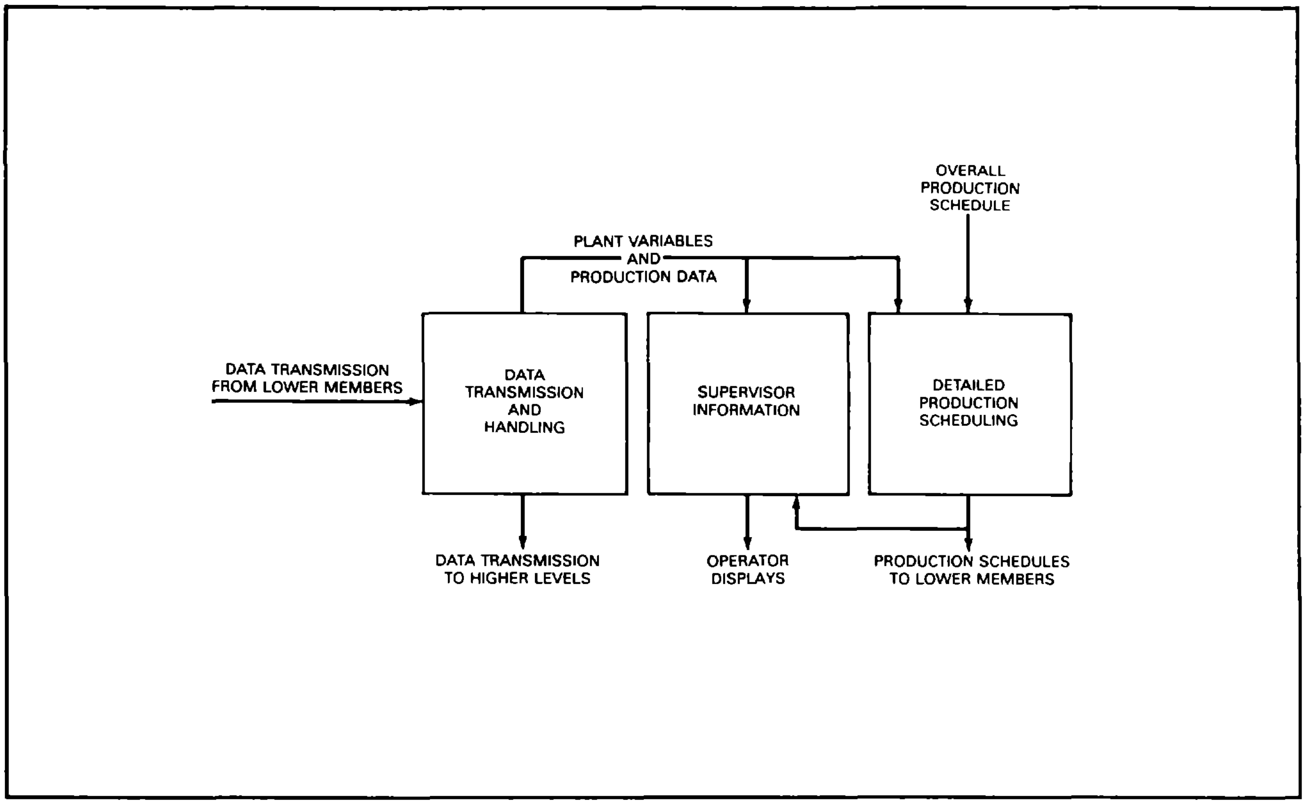

Figure 3-9 A block diagram of the intermediate production scheduling level (Level 3) of an overall process control system.

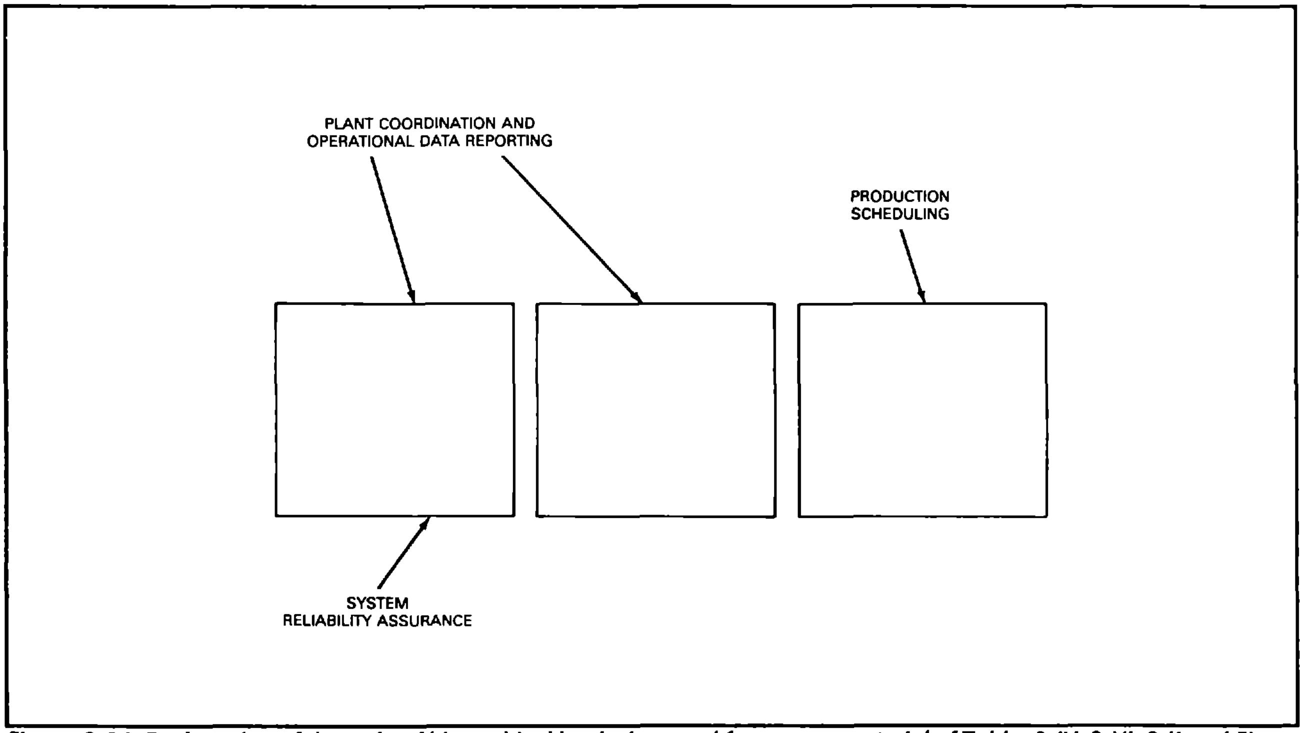

Figure 3-9A Explanation of the tasks of hierarchical levels three and four versus material of Tables 3-IV, 3-VI–3-X and Figure 3-6.

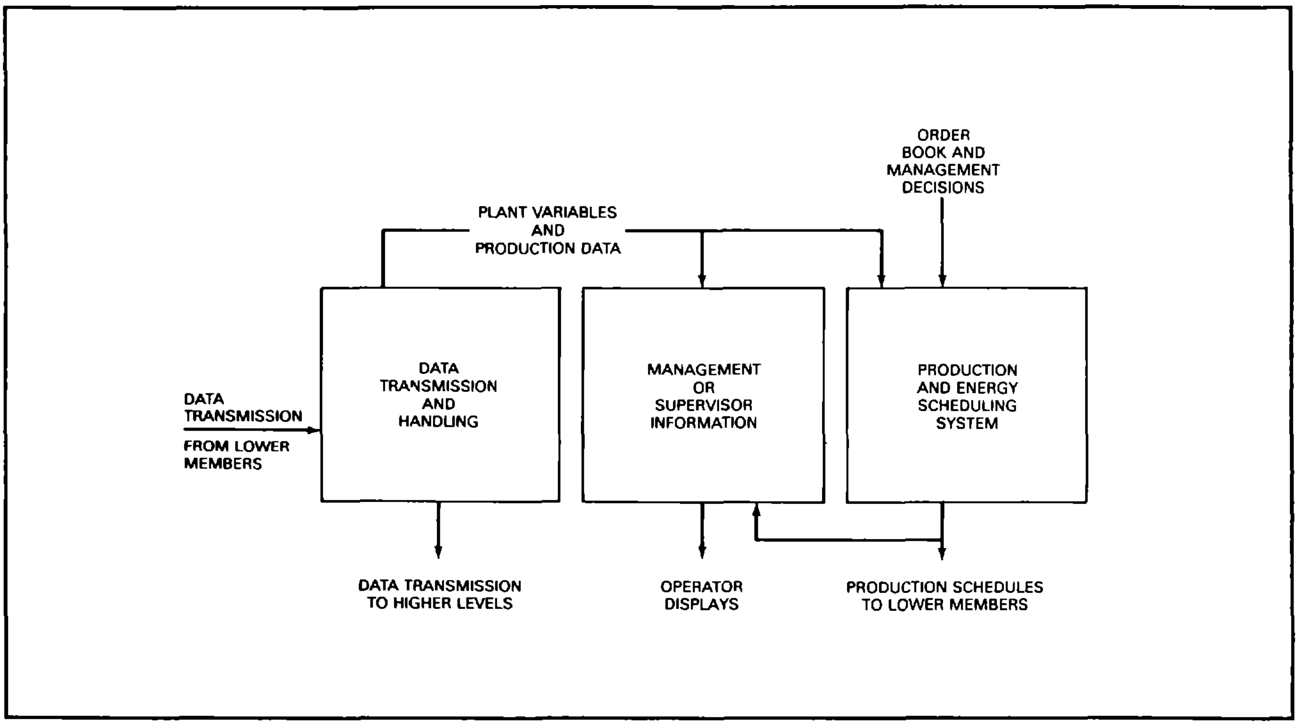

Figure 3-10 A block diagram of the production sheduling level (Level 4A) of an overall process control system.

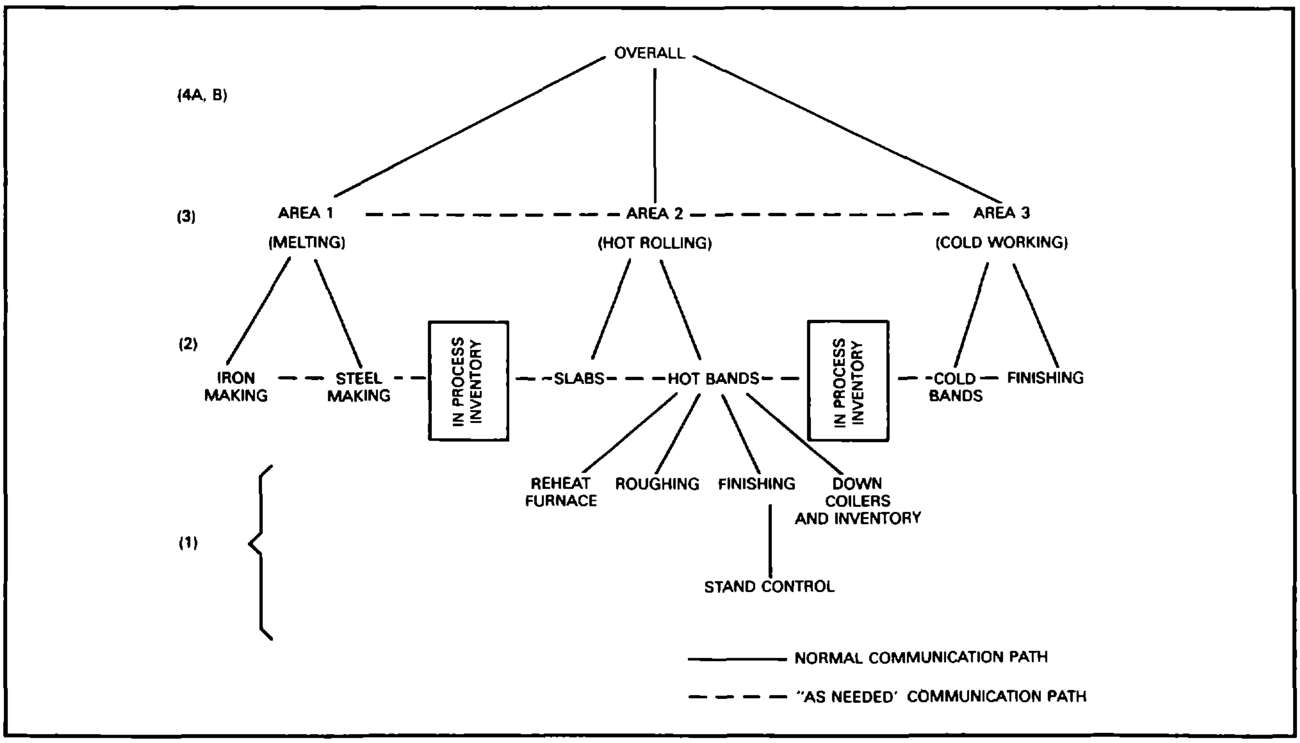

Figure 3-11 Hierarchy arrangement of the steel plant control to show relationship of hierarchy to plant structure.

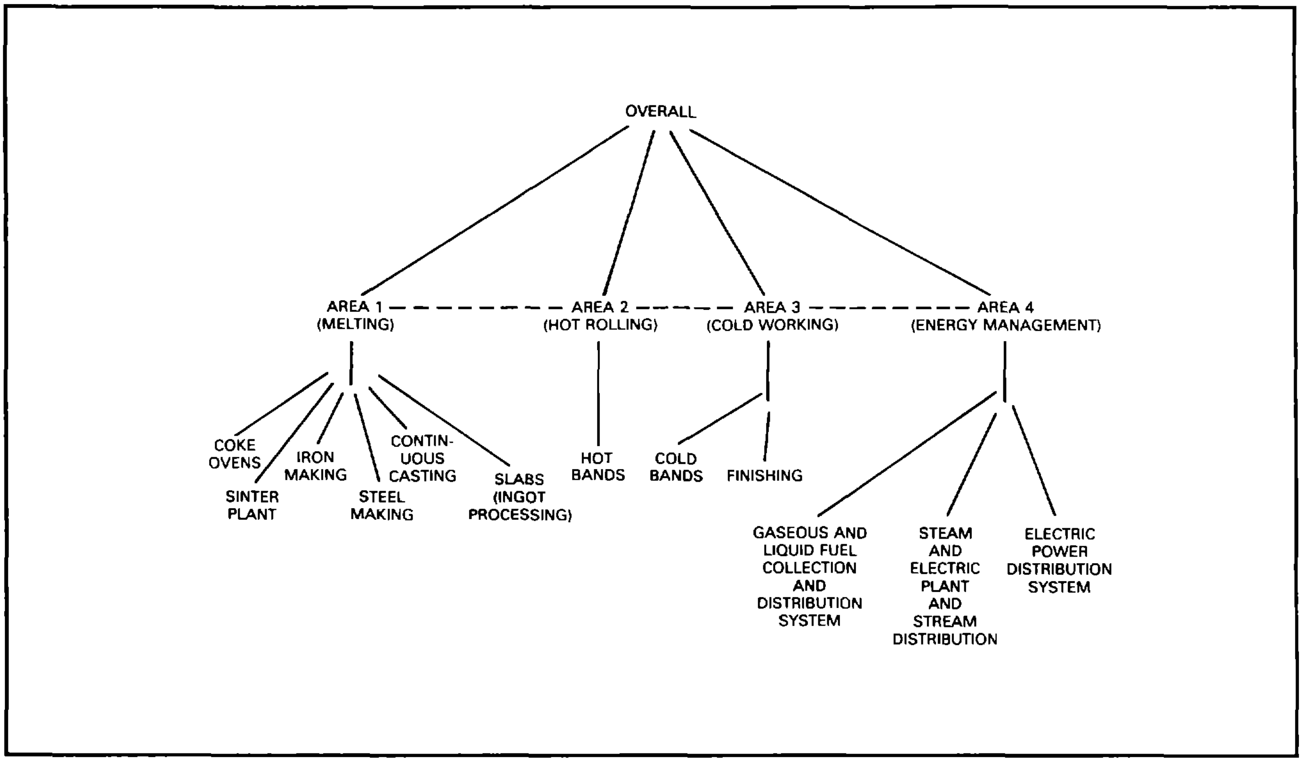

Figure 3-12 Hierarchy arrangement of the Steel Plant control system as studied for energy optimization.

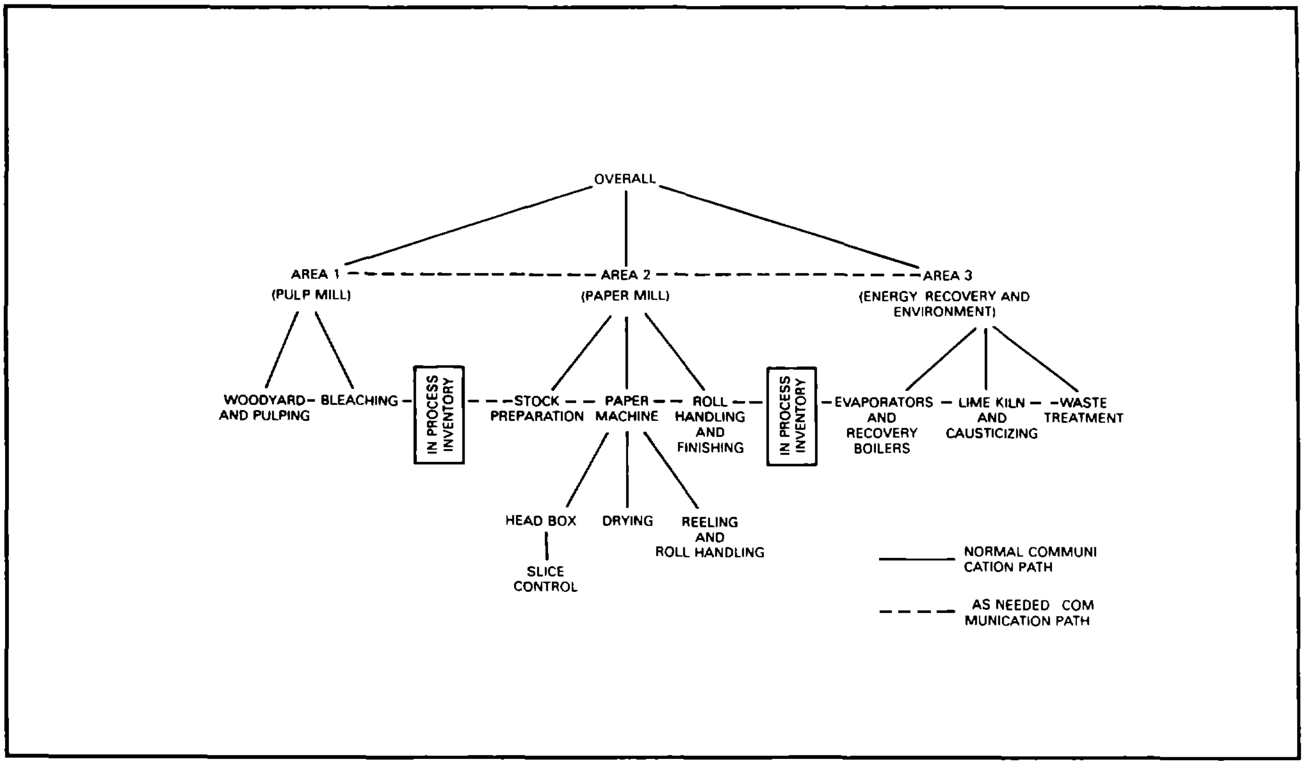

Figure 3-13 Hierarchy arrangement of the Paper Mill control to show relationship of hierarchy to plant structure.

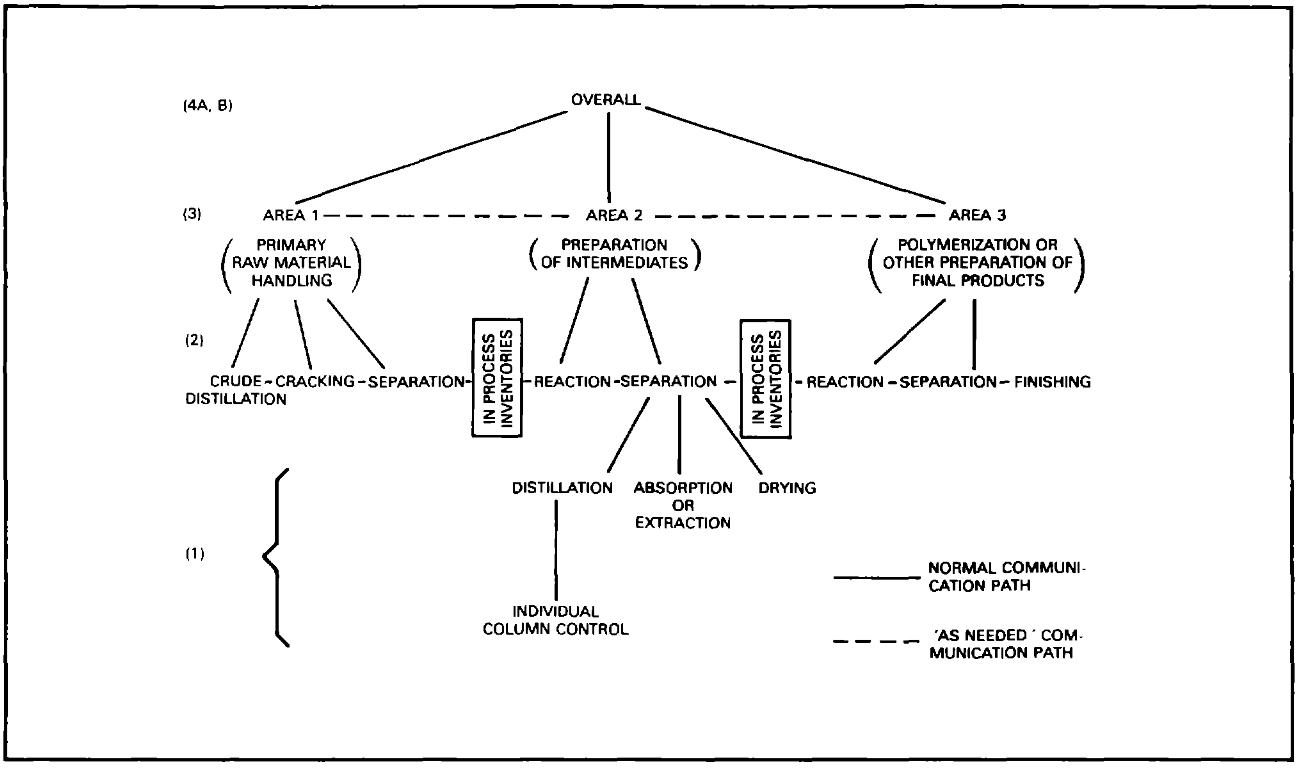

Figure 3-14 The hierarchy control scheme as applied to a Petrochemical Plant.

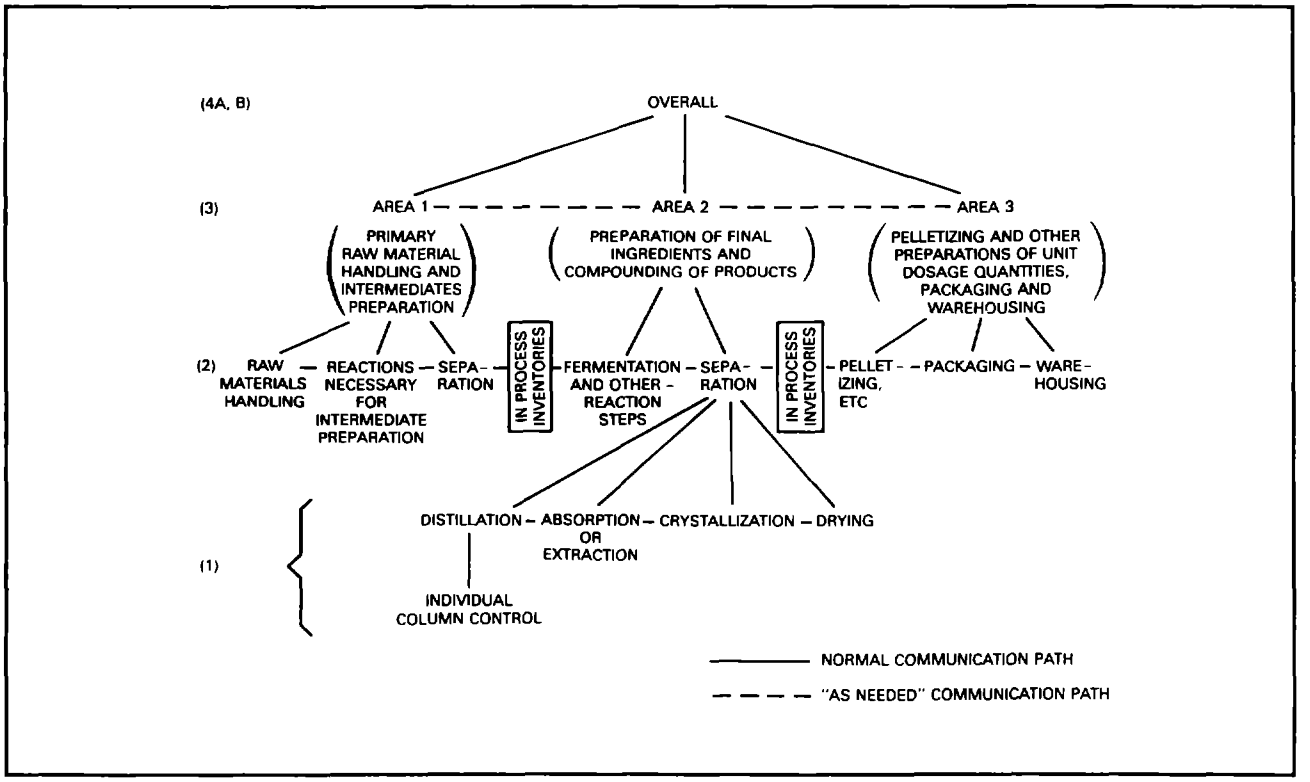

Figure 3-15 The hierarchy control sheme as applied to a Pharmaceuticals Plant.

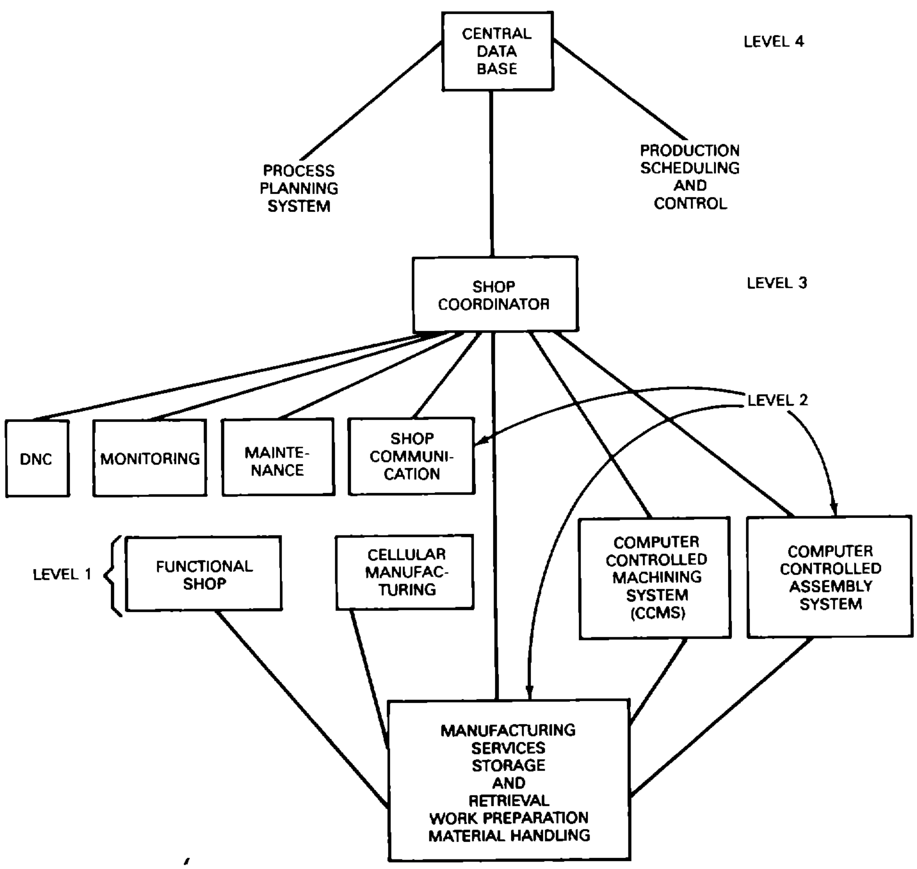

Figure 3-16 Computer Integrated Manufacturing System (CIMS) (Cincinnati-Milacron proposal).