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FACILITIES AND ENVIRONMENTAL EFFECTS
SURFACE PREPARATION AND COATINGS
DESIGN/PRODUCTION INTEGRATION
HUMAN RESOURCE INNOVATION
MARINE INDUSTRY STANDARDS
WELDING
INDUSTRIAL ENGINEERING
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U.S. DEPARTMENT OF THE NAVY
CARDEROCK DIVISION,
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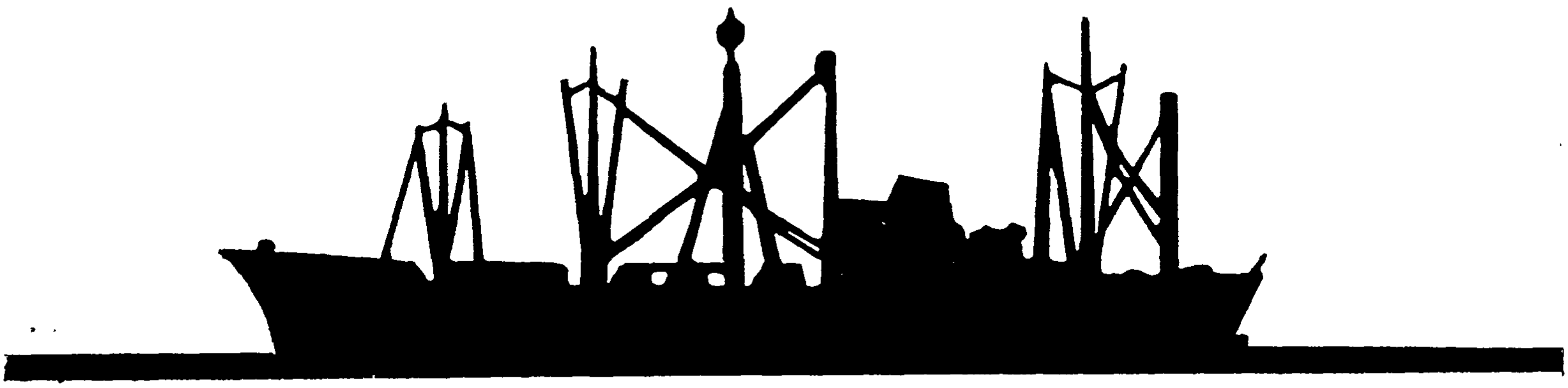

INSTITUTE FOR RESEARCH AND ENGINEERING FOR AUTOMATION AND PRODUCTIVITY IN SHIPBUILDING

I R E A P S

SMALL SHIPYARD PRODUCTIVITY INCREASES THROUGH INTEGRATED MANPOWER, SCHEDULE AND MATERIAL CONTROL

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1.0 SUMMARY

The authors describe the need for fully integrating all aspects of shipbuilding so that current resources can be utilized in the most effective and cost-efficient way possible. The integration of manpower, scheduling, and material control using mini-computer planning, and cost/schedule control systems have proved to be extremely beneficial to small and medium sized shipyards. These systems have given management an added insight into areas that have been troublesome. Now, corrective action can be applied and the results measured quickly, directly, and accurately.

By integrating all efforts of the shipyard plan, relative merits of new production techniques can be measured and evaluated. This extension of management visibility and control permits the shipyard to implement new technologies with far more confidence than possible before.

2.0 INTRODUCTION

The over-riding concern in shipbuilding today is how to increase productivity in the best way possible.

Much of the current difficulty North American shipyards face is an inability to compete on the world market because, quite simply, our ships cost too much. Costs for labor and material have escalated to the point where the free market system can no longer guarantee that our shipyards will compete successfully with shipyards abroad.

And while we face very high unit costs for labor and material, the fact remains that our productivity (the measure of our success in utilizing these resources) has declined greatly. Foreign shipyards, on the other hand, have implemented new processes and procedures that utilize the resources needed for ship construction far more efficiently, regardless of the higher unit costs involved.

Considerable attention has been focused upon the benefits of computer-aided design (CAD) and computer-aided manufacturing (CAM). Surely these applications have great potential. But while the promised benefits of these new systems is most encouraging, too often too little thought. is directed to what can be done to make existing facilities and resources more efficient and productive.

What needs to be asked is this: why do foreign yards build ships with HALF or less production manhours than do North American yards? The answer can be found not so much in their more advanced facilities and "high-tech" engineering, but in their management and production techniques.

Productivity very definitely depends upon organization and can be increased with

a) Systematic planning and production engineering before production starts

b) Detailed monitoring of production progress

c) Regular feedback of results to ensure continual improvement in planning and control

d) Informed and resourceful management that can implement changes wherever and whenever needed

Ship production is complex and requires an interlinking of many plans and requirements. And while many shipyards pride themselves on their ability to plan, they too often do not apply sufficient resources and proper tools to do the job properly. What results is a production "plan" that does not coordinate the various participants of the project, and the ensuing confusion not only increases current production costs but also obscures exciting new cost and schedule savings opportunities for future work.

The planning effort, therefore, should focus upon not only how best to maintain cost and schedule today, but also how to continually refine this planning process so that costs can steadily be driven downward and schedules shortened. This feedback loop obviously requires an ability to bring together ("integrate") all requirements for manpower, schedule, and material.

The ship design, planning and management efforts must concentrate together and find new ways to make ships easier and faster to build.

This process, to its conclusion, will enable today's shipyard to be considerably more competitive tomorrow.

3.0 THE INTEGRATED SYSTEMS SOLUTION

Small and medium sized shipyards are now gaining sizeable benefits from applying more efforts to planning and production engineering. These areas form the foundation by which shipyard resources (manpower, facilities and material) can be successfully coordinated. The advent of the inexpensive mini-computers and software systems available have augmented these efforts so that the coordination ("integration") of the various areas of the shipyard can be assured, monitored and controlled to best advantage.

The system uses a multiple module philosophy in which all modules are interconnected under user control, or can be run independently for specific application. The main modules are referred to by their trade names of PERT-PAC, WORK-PAC, and MAT-PAC.

PERT-PAC: A job scheduling system based upon the critical path method and enhanced by specialized techniques for automating network updates and re-scheduling. PERT-PAC's Micronet library functions reduce planning time and improve network data accuracy.

WORK-PAC: A production labor planning and control system based upon the work package concept, employing statistical techniques for automating job progress and final total cost projections on a continuous basis.

MAT-PAC: An interactive material requirements planning, purchasing and delivery control system designed to expedite project material planning and procurement.

P L A N N I N G & P R O D U C T I O N E N G I N E E R I N G

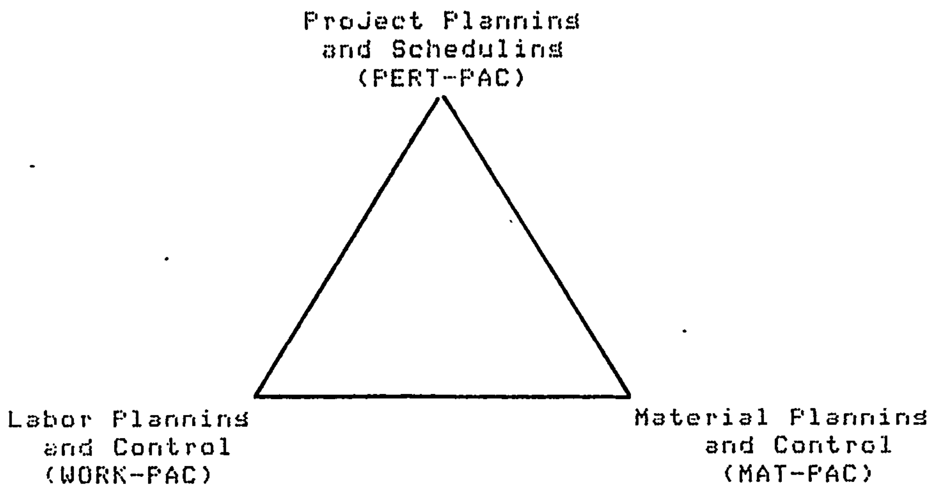


FIGURE 3.0.1

Integrated Project Planning & Management Control System Triad

3.1 PLANNING & PRODUCTION ENGINEERING

The planning and production engineering processes must be tied together and both require a certain amount of lead time to be successful. During this time the design process must examine and evaluate various techniques that best exploit the production process:

a) Techniques which allow more extensive application of production engineering procedures in the time available - however short. These are concerned with digesting general experience to improve producibility through more and better standardization in the yard.

b) Techniques which themselves reduce the necessity for lead time. These are mainly concerned with the application of computer methods to the design development and production information processes.

c) Techniques which maximize production efficiency. For example, the pre-assembling of material items in the shop environment is often significantly less expensive than if the assembly were done at the job site (i.e., on board ship). Not only is there less opportunity for adding to costs from extra crew transfers and gathering together all needed equipment and materials at remote locations, but also climatic conditions and personnel morale within the production environment can bear heavily upon the ultimate cost of the effort.

The lead time requirement is a product of the level of technology employed and the balances chosen within total contract execution. In making the transition to longer lead times, the demands of the orderbook will be a dominant factor in order to achieve continuity of production. This implies a phasing of the implementation of planning and production engineering procedures to suit each individual yard for the given occassion.

Procedures, particularly those relating to geometry and block breakdown, do not of themselves affect lead time significantly. Other procedures, particularly equipment and ship module techniques, do require an investment both in time and manpower to realize the potential benefits. In these cases it is necessary to review and define the extent of implementation.

The planning and production engineering processes must be supported by an organizational structure and sound operational procedures to assure adequate feedback from the production facilities to the Drawing Office for updating and validating of drawings.

3.2 SCHEDULING

The preliminary planning for the project is based upon detail knowledge of the shipyard resources, contract specifications, the general arrangement drawings, milestone target dates and shipyard holiday schedule.

The project schedule is developed with a critical path network. Standardized planning modules, called Micronets, are developed for various stages of the project. Data collected by the planners include the steel erection sequence, equipment lists and related foundations, and preliminary plans ("ideas") for zone outfitting, modularization and unit pre-outfitting.

The successful execution of the network schedule depends upon a numbering system where a unique number for each segment of the network is assigned and cataloged. The vessel is sectioned into manageable zones and units with discrete identification numbers which remain unchanged throughout the project. Developing the project network is an evolutionary process. The stages for the project are as follows:

a) Review the Master Schedule

b) Develop network plans and options

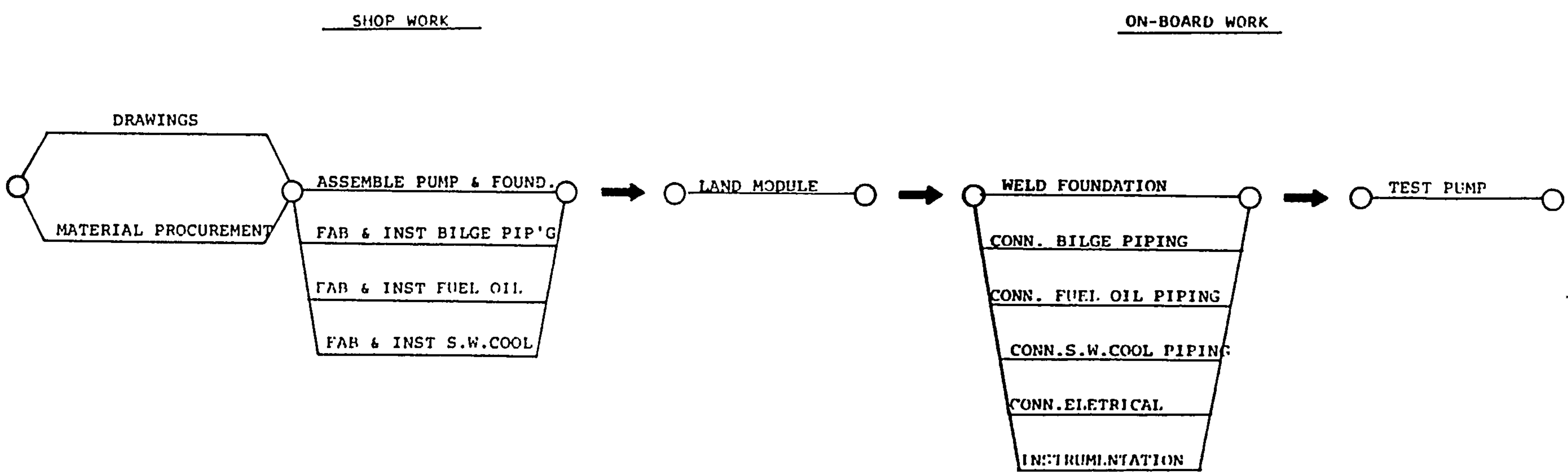
c) Develop the steel Micronets detailing all activities for a steel unit from drawings, material procurement, through fabrication and assembly, and finally erection and finish welding

d) Build the network by transferring all steel unit Micronets and linking them at erection in their natural sequence

e) Build and install erection and/or assembly constraint dummy activities to ensure unit erection sequence is correct (for example, deck units cannot be erected until side units are in place)

FIGURE 3.1.1:
Sample Multiple Ship System Outfit Module

OUTFIT MODULE
Salt Water Circulating Pump



f) Provide broad-scale zone outfit activities that are brought together for zone and system tests

d) Install sea trials and delivery activities

h) Revise and refine milestones for summary overview purposes

i) Set start-off link activity to begin erection on anticipated start date

j) Process network, review milestone schedules, approve the erection sequence, and plot the erection sequence

k) Develop equipment module Micronets complete with durations, link to all procurement as appropriate

1) Transfer equipment module Micronets to network

m) Develop main machinery installation sequence complete with drawings and material procurement activities

n) Develop zone outfitting Micronets complete with drawings and material procurement

0) Develop unit pre-outfitting Micronet complete with drawings and material procurement

P) Develop tank and systems' testing Micronets

q) Transfer Micronets to network. Process and review.

The Plan Schedules undergo two discrete phases of development before being fully usable by Production. These are

a) Network planned schedules

b) Resource loaded schedules

Network planned schedules reflect dates as directly generated by the PERT-PAC Main Processor and represent the most attainable dates limited only by the activity sequences. Network planned schedules can be obtained at any time during the developmental phase of the network and are used to validate the overall sequence of work represented by the network.

FIGURE 3.2.1:
Sample Steel Assembly Micronet

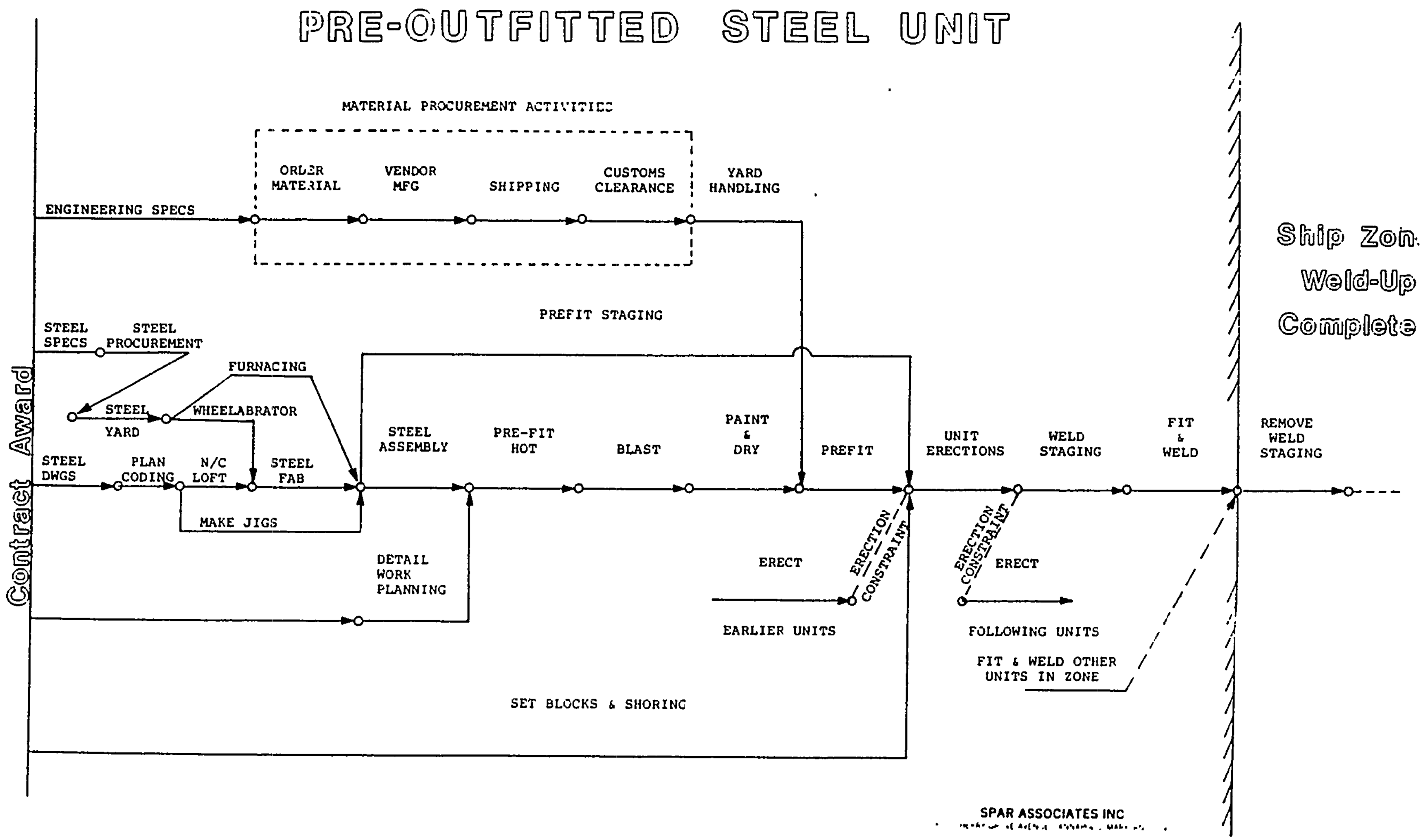
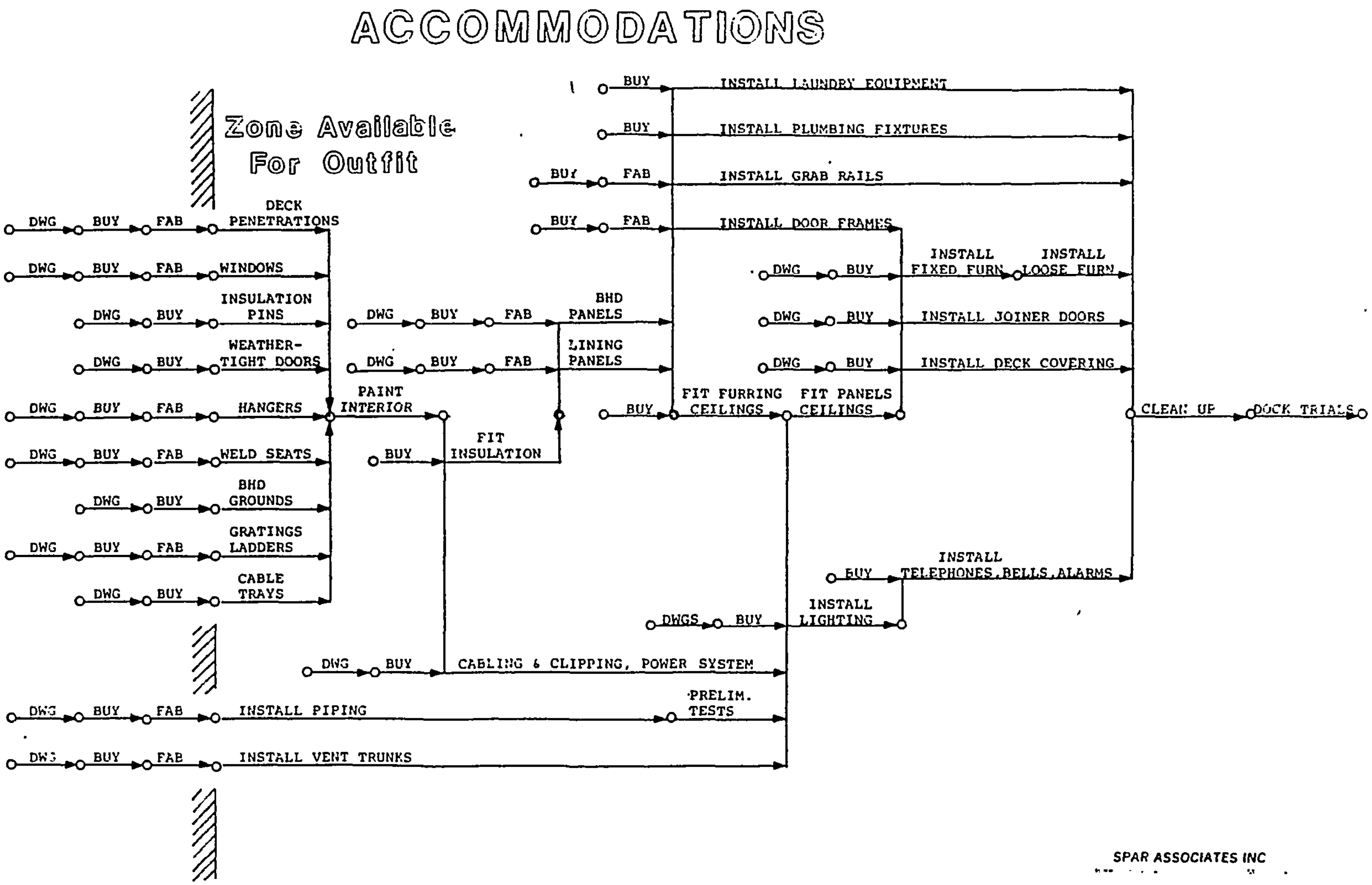


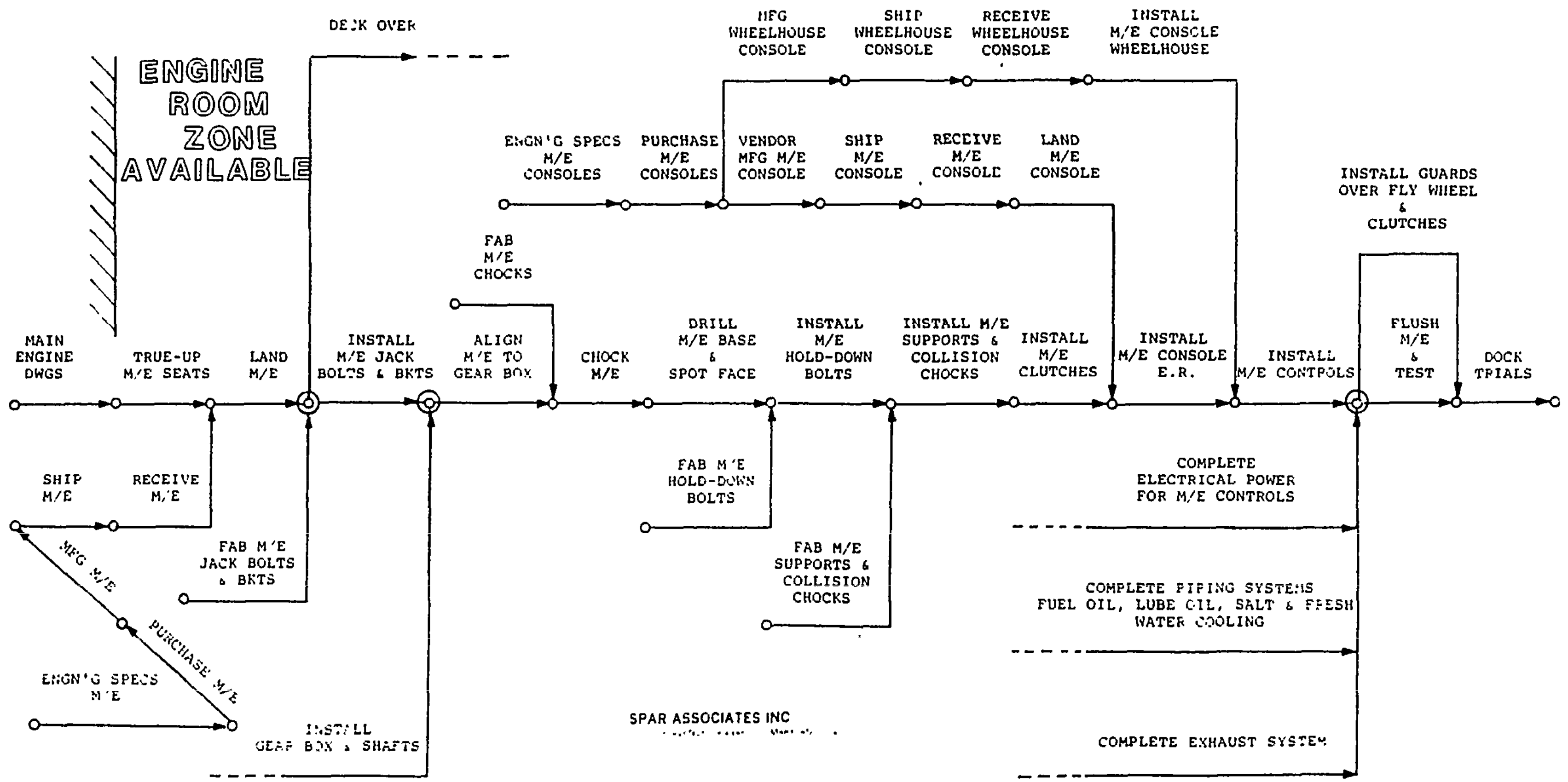
FIGURE 3.2.2:
Sample Accommodations Micronet



SPAR ASSOCIATES INC

FIGURE 3.2.3:
Sample Machinery Systems Micronet

MAIN ENGINE



Resource loading allows specific restrictions of available resources (manpower, floor space, etc.) to influence the schedules further.

Resource loading normally is not applied until the network is generally complete and the correct work sequencing fully established. The loading process entails determining budgets, steel unit sizes (for floor space restrictions, etc.), facilities and manpower availabilities. Resource loading is done using either the PERT-PAC Allocator subsystem or the WORK-PAC Manpower subsystem. Both methods accomplish the same result, except that the Allocator does handle non-labor resources, while Manpower cannot. Results from the resource Loadings, including revised schedules, are transferred back to the network from either subsystem.

3.3 LABOR PLANNING AND CONTROL

Shipyard management has a continuous need to measure work progress and manhour performance so that any problems that develop hopefully can be remedied before they become critical.

Most shipyards manually assess physical progress and this approach always depends entirely upon an individual's interpretation of the progress and is therefore highly subjective. Manual assessments also cost considerable time and effort.

WORK-PAC is a computer system that 'measures progress and makes final manhour cost projections objectively and continuously based upon actual statistically-derived productivity information continuously being supplied to the system. WORK-PAC further summarizes performance trends not only by the project work breakdown structure, but by the shipyard's organization structure (work centers, departments, and trades) as well. This visibility is valuable not only to planning management, but also to production control supervisors.

The WORK-PAC manpower planning and control procedures are developed using the work package concept throughout:

a) New ship construction

b) Ship repair projects

c) Commercial engineering projects

d) Shipyard maintenance and overhead work

Cost Accounts (WBS or engineered ship systems) require contributions of effort from many areas of the shipyard organization (see Figure 3.3.1 for an illustration of a logical distribution and sequencing of work effort). Each of these separate and distinct efforts form the basis of the work package scheme for an account and are fairly easy to establish since they provide the fundamental plan by which the project shall be executed, REGARDLESS OF BUDGET, SCHEDULE, OR EVEN ENGINEERING DETAILS.

The work package represents a distinct and definable unit of work that starts and completes ideally without significant interruption, under the direction of a single authority or work center. The scope of work can be clearly identified, and the work package can be budgeted and scheduled.

Work packages are developed precisely in the manner consistent with the way shipyard production will perform the work. Production will normally accomplish its effort as a logical set of steps; the work package, while including a selected number of these steps, will be so defined to correlate directly with appropriate tasks and operations.

The approaches of pre-outfitting, modularization (outfit on block) and mass production techniques all are attempts to make the most of available resources with minimum attending costs. The labor planning and control system, WORK-PAC, provides a convenient means to develop work packages that support these efforts WITHOUT altering the basic work breakdown structure for cost budgeting and actual cost collection. These production techniques are not the result of any dramatic change in planning or production philosophies or even in the structuring of the project's chart of accounts, but merely upon the re-ordering of work according to a better scheduling approach. Indeed, scheduling does have a definite bearing upon the cost of any endeavor.

Work packages are developed so that when completed, there is a clear track as to precisely what has been accomplished. Further, WORK-PAC summarizes work package performance and provides performance trend information valuable for continued production monitoring and control.

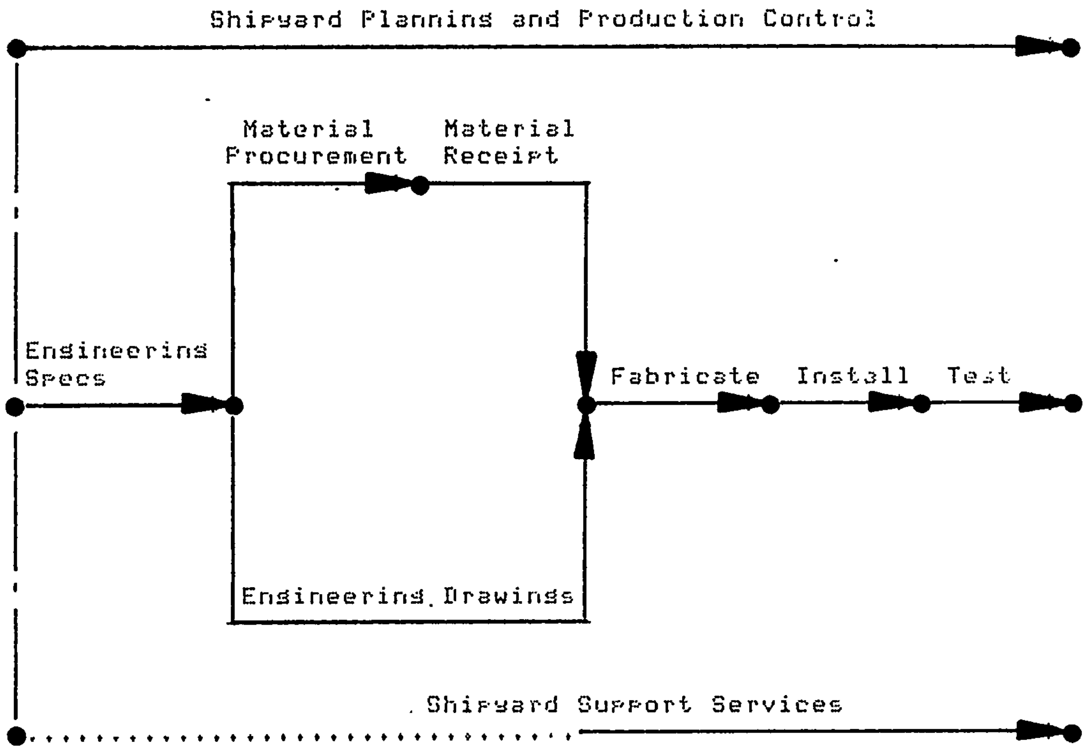


FIGURE 3.3.1: Basic Identification Of Ship System (Cost Account) Work Packages

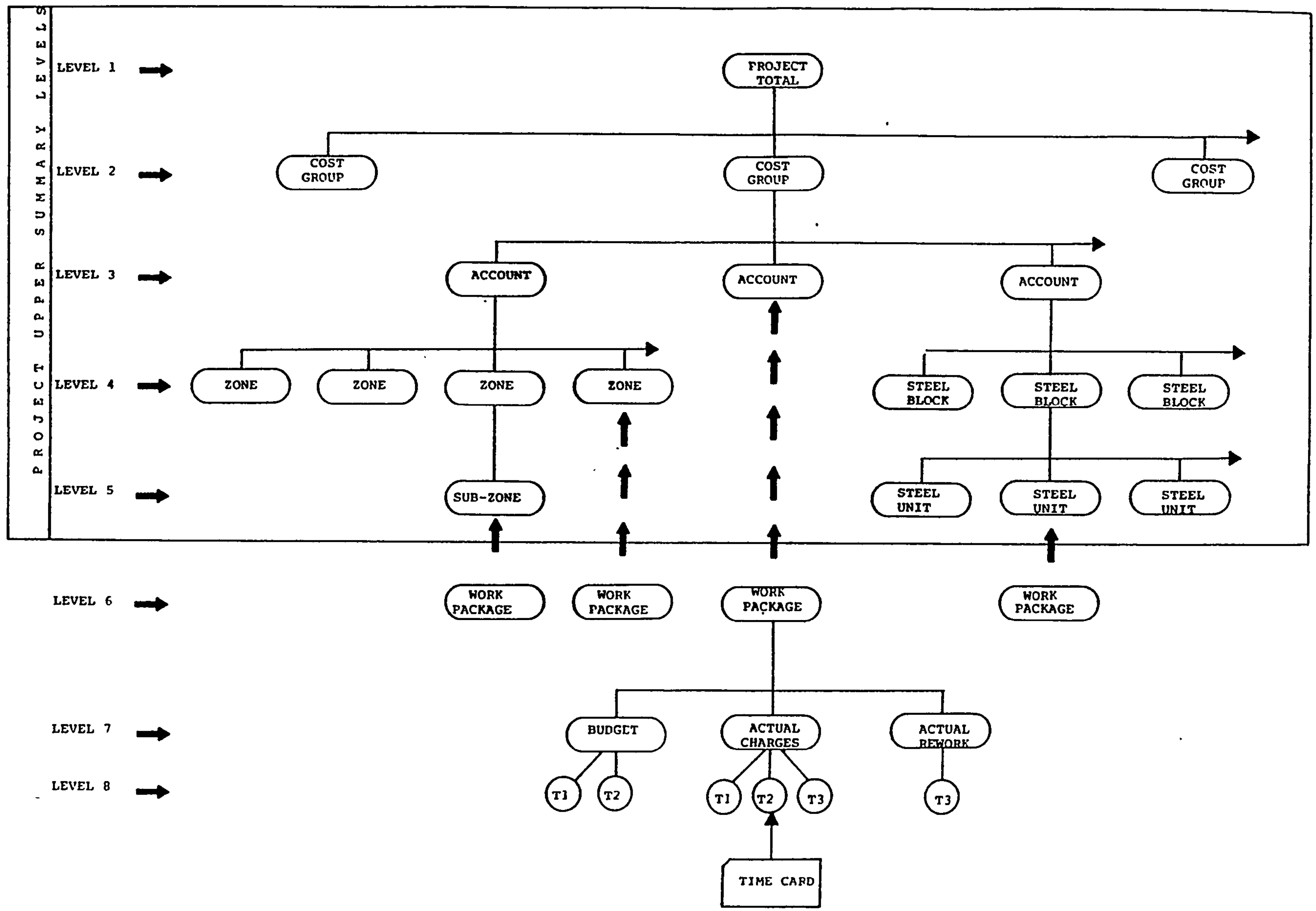


FIGURE 3.3.2:
Labor Planning & Control System Work Breakdown Structure

REPORT (21.2) 1001 1000 FT TEST SHIP 25AUG79

COST PERFORMANCE REPORT - WORK BREAKDOWN STRUCTURE
PROJECT SUMMARY

	CURRENT PERIOD SINCE 18AUG79					CUMULATIVE TO DATE					AT COMPLETION		
WBS	BCWS	BCWP	ACWP	SCHED VAR	COST VAR	BCWS	BCWP	ACWP	SCHED VAR	COST VAR	BUDGET	EAC	VARIANCE
0	16638.	11287.	15544.	-5351.	-4257.	203002.	189324.	190631.	-13618.	-1247.	471566.	474670.	-3104.
1	121.	331.	265.	210.	66.	650.	1350.	1281.	700.	69.	54182.	51412.	2770.
2	980.	704.	708.	-276.	-4.	7761.	4696.	4650.	-3065.	46.	53980.	53450.	530.
3	928.	934.	995.	6	-61.	7828.	8707.	8909.	879.	-102.	82250.	83216.	-966.
4	1484.	1705.	1717.	221.	-11.	17420.	8339.	8318.	-9081.	22.	79608.	79402.	206.
5	451.	360.	361.	-92.	-1.	1943.	804.	804.	-1139.	0.	27662.	27661.	1.
6	691.	148.	149.	-543.	-1.	1990.	310.	310.	-1679.	-0.	57419.	57420.	-1.
7	1875.	1.	2217.	-1874.	-2216.	41210.	33328.	31461.	-7882.	1867.	124426.	120243.	4183.
8	267.	47.	57.	-220.	-10.	6832.	1410.	1432.	-5422.	-21.	15123.	15353.	-230.
9	595.	208.	279.	-387.	-71.	19792.	22117.	22117.	2325.	0.	33784.	33784.	0.
SUB TOTAL	24029.	19942.	22289.	-4087.	-2346.	308427.	270724.	269807.	-37703.	917.	1000000.	996612.	3383.
MANAGEMENT RESERVE											60000.		60000.
TOTAL DIRECT LABOR											1060000.	996612.	63388.

WBS = WORK BREAKDOWN STRUCTURE (GROUP OR COST NO.)
BCWS = BUDGETED COST (MANHRS) OF WORK SCHEDULED TO-DATE
BCWP = BUDGETED COST (MANHRS) OF WORK PERFORMED TO SAME PROGRESS TO-DATE
ACWP = ACTUAL COST (MANHRS) OF WORK PERFORMED TO-DATE
SCHED.VAR. = SCHEDULE VARIANCE (MANHRS) BETWEEN WHAT PLANNED AND WHAT WAS ACTUAL FOR CURRENT PROGRESS (BCWP-BCWS)
COST VAR. = COST (MANHRS) VARIANCE TO-DATE (BCWP-ACWP)
EAC = ESTIMATED (MANHR COST) AT COMPLETION

NEGATIVE VARIANCES INDICATE COST OVER-RUN OR SCHEDULE SLIPPAGE

FIGURE 3.3.3:
Sample WORK-PAC C/SCS Performance Report
(WBS Cost Group Summary)

REPOPT (23.) 1001 1000 FT TEST SHIF 25AUG79

COST PERFORMANCE REPORT - WORK CENTER BREAKDOWN
PROJECT SUMMARY

APEA		CUMULATIVE TO DATE BCWS	BCWF	ACWF	SCHED VAR	COST VAR	AT COMPLETION BUDGET	EAC	VARIANCE
1	STEEL FAB SHOP	37693.	33041.	31999.	-4652.	1053.	78035.	75549	2486.
2	STEEL SUB-ASSEMBLY SHOP	101826.	97203.	96577.	-4624.	625.	133079.	131837.	1242.
3	STEEL ERECTION ON WAYS	18972.	17084.	16217.	-1882.	867.	66200.	64242.	1959
4	WELDING ON-SHIP	22411.	23349.	26185.	938.	-2835.	91271.	102354.	-11083.
5	N.C.	11120.	11236.	9657.	115.	1579.	11892.	10221.	1671.
6	EXPEDITING	11136.	9847.	9414.	-1289.	433.	27027.	25838.	1189.
7	CENTRAL PLANNING	9391.	8021.	6929.	-1360.	1092.	20506.	19174	1332.
9	ENGINEERING & DESIGN	19792.	22117.	22117.	2325.	0.	33785.	33785.	0.
10	PRODUCTION SERVICES	25017.	15753.	15463.	-9264.	290.	85792.	84300.	1492.
11	MISCELLANEOUS SHIP STEEL	10980.	10069.	10013.	-911.	56.	31722.	31546.	176.
15	MISCELLANEOUS SERVICES	3514.	777.	1088.	-2737.	-311.	6223.	7043.	-820.
21	OUTFIT ACCOMODATIONS - SHOPS	175.	96.	96.	-79.	0.	23274.	23274.	0.
22	OUTFIT CARGO SYSTEMS - SHOPS	3489.	1914.	1914.	-1575.	-0.	20066.	20066.	0.
23	OUTFIT MECHANICAL - SHOPS	2546.	2305.	2327.	-240.	-22.	24774.	25010.	-236.
24	PIPE SHOP	6282.	3556.	3556.	-2725.	0.	32091.	32091.	0.
25	MACHINE SHOP	1013.	269.	269.	-744.	0.	11061.	11061.	0.
26	ELECTRICIANS SHOP	753.	0.	0.	-753.	0.	17867.	17867.	0.
31	OUTFIT ACCOMODATIONS - SHIP	475.	1185.	1185.	710.	0.	30900.	30900.	0.
32	OUTFIT CARGO SYSTEMS - SHIP	4272.	2736.	2736.	-1535.	0.	33912.	33912.	0.
33	OUTFIT MECHANICAL - SHIP	5282.	6481.	6481.	1199.	0.	57475.	57475.	0.
34	PIPING - ON SHIP	11139.	4761.	4761.	-6377.	0.	47530.	47530.	0.
35	MACHINISTS - ON SHIP	930.	535.	535.	-395.	0.	16604.	16604.	0.
36	ELECTRICIANS - ON SHIP	1236.	310.	310.	-926.	0.	39553.	39553.	0.
SUB TOTAL		309433.	272646.	269820.	-36787.	2826.	1000639.	1001231.	-592.

	BUDGET	EAC	VARIANCE
UNDISTRIBUTED BUDGET	-639.	-639.	
PROJECT ADJUSTMENTS		-3980.	3980.
SUB-TOTALS	1000000.	996612.	3388.
MANAGEMENT RESERVE	60000.		60000.
TOTAL DIRECT LABOR	1060000.	996612.	63388.

WBS = WORK BREAKDOWN STRUCTURE (GROUP OF COST NO.)
BCWS = BUDGETED COST (MANHRS) OF WORK SCHEDULED TO-DATE
BCWP = BUDGETED COST (MANHRS) OF WORK PERFORMED TO SAME PROGRESS TO-DATE
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COST VAR. = COST (MANHRS) VARIANCE TO-DATE (BCWP-ACWP)
EAC = ESTIMATED (MANHR COST) AT COMPLETION

NEGATIVE VARIANCES INDICATE COST OVER-RUN OR SCHEDULE SLIPPAGE

FIGURE 3.3.4:
Sample WORK-PAC C/SCS Performance Report
(Work Centers)

REPORT (22.) 1001 1000 FT TEST SHIP 25AUG79

COST PERFORMANCE REPORT - TRADE BREAKDOWN
PROJECT SUMMARY

TRADE	CUMULATIVE TO DATE					AT COMPLETION		
	BCWS	BCWP	ACWP	SCHED VAR	COST VAR	BUDGET	EAC	VARIANCE
1 AIR TOOL ROOM	683.	222.	233.	-461.	-11.	4899.	4909.	-11.
2 BLACKSMITHS	530.	774.	925.	245.	-151.	2928.	3340.	-412.
4 PLANT MAINTENANCE	0.	0.	7.	0.	-7.	0.	[illegible]	-7.
5 BURNERS	22314.	21856.	21919.	-458.	-63.	56922.	57037.	-115.
6 CARPENTERS - SHIP	10246.	10390.	10310.	144.	80.	47743.	47339.	405.
7 CHIPPERS & CAULKERS	4290.	3410.	2279.	-881.	1132.	14435.	14131.	305.
8 CRANEMEN	6859.	7165.	7220.	306.	-55.	20270.	20332.	-61.
9 DRILLERS & REAMERS	35.	27.	54.	-8.	-27.	682.	709.	-27.
10 ELECTRICIANS	4590.	1295.	1336.	-3295.	-41.	59804.	59845.	-41.
11 FITTERS	32295.	30054.	29558.	-2241.	496.	66322.	65152.	1170.
13 FURNACEMEN - SLAB	1485.	1420.	1433.	-65.	-13.	1662.	1675.	-13.
14 JOINERS	631.	557.	564.	-74.	-7.	35135.	35142.	-7.
15 LABOURERS	4100.	3022.	3010.	-1078.	12.	29169.	28994.	175.
16 MACHINISTS	2837.	4843.	4884.	2007.	-40.	16122.	16162.	-40.
17 MOULD LOFT	12148.	11780.	10218.	-368.	1562.	12446.	10795.	1650.
18 PAINTERS	2077.	2218.	2267.	141.	-49.	19862.	20140.	-278.
21 PIPE FITTERS	9300.	2681.	2710.	-6619.	-28.	32797.	32826.	-28.
22 PLUMBERS	1457.	8.	19.	-1449.	-11.	24216.	24227.	-11.
23 POWER HOUSE	0.	0.	3.	0.	-3.	0.	3.	-3.
24 PUNCH SHED	7213.	6224.	5384.	-989.	840.	13164.	11293.	1871.
25 RIGGERS	10547.	8067.	7065.	-2480.	1001.	35039.	34174.	866.
27 SHEET METAL WORKERS	327.	471.	484.	144.	-12.	12196.	12208.	-12.
28 STAGE BUILDERS	4269.	3324.	3308.	-946.	15.	22743.	22575.	169.
29 STOCKYARD - STEEL	4427.	4993.	6651.	566.	-1658.	10127.	13489.	-3362.
30 STORESMEN	3596.	3146.	2330.	-450.	816.	8681.	8131.	550.
31 TRUCK DRIVERS	2615.	2100.	1412.	-515.	689.	7969.	7724.	245.
33 WELDERS - ELECTRIC	79365.	68672.	68650.	-10693.	21.	231000.	230143.	857.
34 NIGHT FOREMEN	121.	32.	81.	-88.	-48.	270.	319.	-48.
35 PREPARATION FITTER	15184.	16362.	15856.	1178.	506.	27186.	26292.	895.
36 SHIP FITTERS	9917.	6594.	5098.	-3323.	1496.	45011.	44570.	441.
37 MACHINISTS - OS	2857.	1526.	1547.	-1331.	-22.	26223.	26245.	-22.
38 INDUST.ENGINEER	0.	0.	99.	0.	-89.	0.	89.	-89.
40 DRAWING OFFICE	19791.	22117.	22117.	2326.	0.	33784.	33784.	0.
41 PLANNING	6290.	6172.	6246.	-118.	-74.	13750.	13915.	-165
42 QUALITY CONTROL	3091.	2643.	659.	-448.	1974.	6757.	6564.	192.
99 WELDERS - TACKING	18924.	21260.	23886.	2336.	-2626.	47587.	50801.	-3214.
SUB TOTAL	304413.	275427.	269820.	-28987.	5606.	986900.	985077.	1823.
UNDISTRIBUTED BUDGET						13100.	13100.	
PROJECT ADJUSTMENTS							-1565.	1565
SUB-TOTALS						1000000.	996612.	3388
MANAGEMENT RESERVE						60000.		60000
TOTAL DIRECT LABOR						1060000.	996612.	63388

FIGURE 3.3.5:
Sample WORK-PAC C/SCS Performance Report
(Trades)

3.4 MATERIAL PLANNING AND CONTROL

The material control problem for shipyards dealing with large-scale projects is far different and more complex to solve than that for manufacturing companies producing quantities of like products.

Shipyards manufacture essentially one-off products, each customized to suit a given contract. The material requirements, therefore, are largely specific to the contract, specially purchased and individually expedited to keep pace with production. Inherently, this places a premium emphasis upon the scheduling of this material procurement process. Furthermore, the high cost of material storage and handling and the recent high costs of financing stock inventories have made direct purchasing of material far more necessary than was the case years past. Now there is little room to ignore delivery problems, since the shipyard has virtually no chance to make up for any delays or losses with a subsequent production run. A shipyard must be successful on each and every vessel, or face severe financial difficulties. And the pressure of shipyards competing against one another under limited marketing opportunities requires that a successful yard offer not only a less expensive ship, but also one that can be built faster than the competition.... and too often faster than the declines of the financial markets, which can quickly dry up a ship order before the keel is laid.

MAT-PAC is fully integrated with the scheduling system, PERT-PAC. This helps ensure that the material procurement and delivery functions meet the needs of production with minimium difficulties. PERT-PAC develops the schedules which incorporate not only constraints by production, but also those in other areas, including engineering and material. In response, MAT-PAC updates PERT-PAC with current delivery status so that any delays can be analyzed directly and their impact upon production measured. PERT-PAC keeps track of all schedules and provides a convenient means to coordinate all efforts and ensure that management focuses its attention mostly upon high-priority problems.

MAT-PAC permits material to be purchased directly for a given project, and from stock inventories. While most other material systems accommodate the latter,the direct purchase problems are rarely addressed adequately for the shipyard environment. Further, the scheduling features of MAT-PAC provide a means to determine WHEN scheduled contract demands upon stocks require re-ordering. Again, the importance of the scheduling cannot be overstated. This visibility of future material requirements not only ensures that production needs are satisfied both today and tomorrow, but also that opportunities for reduced costs possible from bulk buying can be better exploited.

MAT-PAC permits material requirements to be fully defined by detail requisitions. However, shipbuilding is often known to begin the material purchasing functions long before actual engineering drawings and bills of material are available. MAT-PAC provides this necessary flexibility without losing control of the procurement process.

Since schedules are so important, MAT-PAC provides a strong capability to ensure requests for quotations ("RfQs") are issued and supplier responses received on a timely basis. The system also sets schedules for ensuring timely issuing of subsequent purchase orders and their acknowledgements by suppliers. MAT-PAC further provides a capability to input and store a full set of material specifications (text information) with requisitions and purchase orders. Once done, many requisitions can be "copied" to future contracts with little change; this reduces manual processing time significantly.

In fact, the copying features of the system even provide the user with simple escalation factors that may be applied to old cataloged prices. This powerful capability not only generates more quickly a complete set of detail material requirements for a new contract, but also a faster material cost estimate. The system easily rolls up new detail estimates to the ship work breakdown structure of cost accounts for summary review.

MAT-PAC has a comprehensive material delivery expediting capability that enables material procurement personnel to concentrate more on critical problems and less upon the non-essential ones.

MAT-PAC has been designed to perform in the real world of a shipyard. It easily handles such problems as fluctuating foreign exchange rates, suppliers that act through brokers, and forecasts cash flow needs for import payments.

MAT-PAC also accommodates such un-planned problems as intra-contract material transfers, which inevitably occur when one contract finds itself short of needed material.

MAT-PAC provides immediate reporting of actual costs against planned budgets. Linked with WORK-PAC, the system generates a full summary of labor and material costs by the familiar ship work breakdown structure.

FIGURE 3.4.1:
Material Planning & Control System Work Breakdown Structure

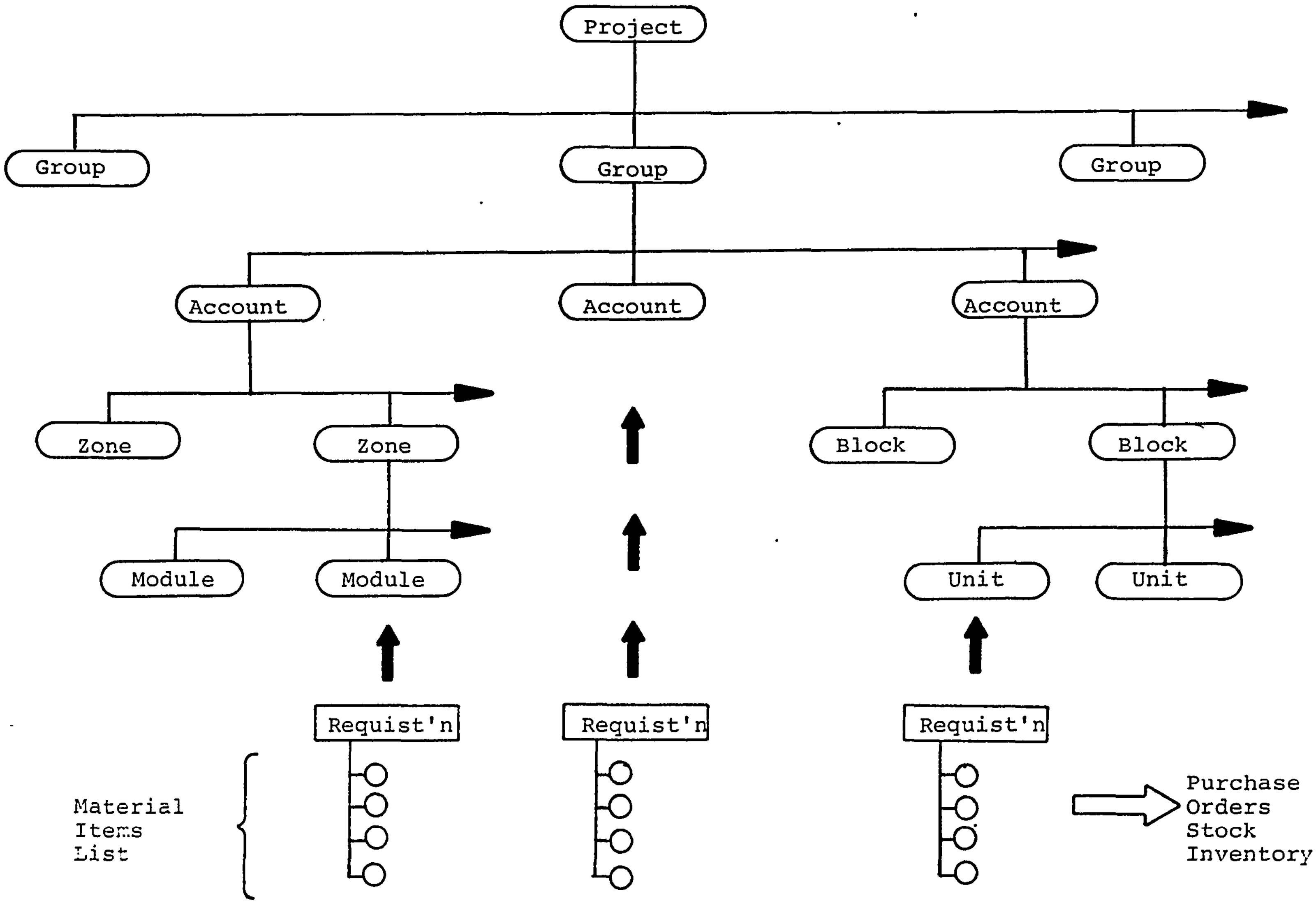

FIGURE 3.4.2:
Sample MAT-PAC C/SCS Performance Report (WBS)

MATERIAL COST PERFORMANCE REPORT

r 'ECT: 450. TEST SHIP
...YSIS DATE: 23AUG82

(Dollars X 1000)

COST ACCT	BCMS	BCMU	ACMU	SCHED VAR	BUDGET VAR	TOTAL BUDGET	MEAC	MEAC VAR
100.	12589.	11254.	11254.	1335.	0.	15245.	15245.	0.
102.	13588.	900.	900.	12688.	0.	14000.	14000.	0.
109.	134450.	80125.	80125.	54325.	0.	250000.	250000.	0.
121.	165988.	80942.	80942.	85046.	0.	248158.	248158.	0.
124.	87450.	80000.	99480.	7450.	-19480.	80000.	99480.	19480.
201.	3265.	3265.	3347.	0.	-82.	3265.	3347.	82.
214.	5447.	0.	0.	5447.	0.	6000.	6000.	0.
216.	784.	458.	458.	326.	0.	840.	840.	0.
225.	987.	715.	882.	272.	-167.	800.	987.	187.
265.	1125.	919.	1002.	207.	-84.	1100.	1200.	100.
301.	3265.	2762.	2578.	503.	184.	4500.	4200.	-300.
3240.	154.	0.	0.	154.	0.	200.	175.	-25.
3580.	3479.	3127.	4581.	352.	-1454.	3500.	5128.	1628.
TOTALS	432571.	264466.	285549.	168105.	-21083.	627608.	648760.	21152.

MANAGEMENT RESERVE 125478.

FIGURE 3.4.3:
Sample MAT-PAC/WORK-PAC Labor & Material Summary Status Report

COMBINED MAT-PAC/WORK-PAC STATUS REPORT

WEEK 12 TUE 17MAR81 PAGE 1

PROJECT 1002. SPAR TEST SHIP II

	TARGETS		CURRENT STATUS			ESTIMATE AT COMPLETION			
	LABOR MANHRS	MATERIAL $ US	SPENT LABOR MANHRS	% PROG	COMMIT. MATERIAL $ US	TOTAL LABOR MANHRS	MANHR SAVINGS	TOTAL MATERIAL $ US	MATERIAL SAVINGS
GROUP 0. STEELWORK	474534.	409530.	474119.	95.	112000.	499147.	-24613.	409530.	0.
GROUP 1. ACCOMODATIONS OUTFIT	55112.	66775.	16832.	28.	11341.	59170.	-4058.	78116.	-11341.
GROUP 2. CARGO SYSTEMS OUTFIT	56325.	0.	28273.	63.	37640.	45235.	11090.	37640.	-37640.
GROUP 3. MECHANICAL SYSTEMS OUTFIT	82615.	0.	48525.	48.	0.	100815.	-18200.	0.	0.
GROUP 4 PIPING SYSTEMS	82362.	0.	49454.	61.	0.	74380.	7982.	0.	0.
GROUP 5. MACHINERY SYSTEMS	27866.	0.	14040.	50.	0.	28210.	-344.	0.	0.
GROUP 6. ELECTRICAL SYSTEMS	57978.	0.	16884.	30.	0.	55686.	2292.	0.	0
GROUP 7 PRODUCTION SERVICES	128516.	0.	85051.	62.	0.	137174.	-8658.	0.	0.
GROUP 8 OWNER CHANGES	7147.	0.	4508.	58.	0.	7737.	-590.	0	0
GROUP 9 DESIGN & DRAWING	27587.	0.	23059.	81.	0	28508.	-921.	0.	0
PROJECT 1002. SPAR TEST SHIP II	1000039.	476305.	760702.	73.	160981.	1036062.	-36023.	525286	-48981
MANAGEMENT RESERVE	55000.	75000.					55000.		75000
TOTALS	1055039.	551305.				1036062.	18977.	525286.	26019

4.0 CONCLUSIONS

Correct project Cost/Schedule management requires a continuous review of production performance and the ability to act quickly to avoid or minimize problems. Correct planning, however, can relieve management of much on-the-spot problem solving, which oftentimes cannot be as successful once the project is under way. Planning identifies problems before they can occur and provides early opportunities to develop strategies that can avoid problems altogether.

The planning phase must concentrate upon not only the proper sequencing of work and establishing performance measurement goals (budgets and schedules), but also must further evaluate relative degrees of cost and schedule risk among project alternatives. Risk, in this sense, *refers to* the likelihood of over-run (time, money, or both) in completing the project.

A "Risk Review" process assesses the relative "softness" versus precision in project definition. Ill-defined (soft) requirements are more highly vulnerable to change and are therefore of higher risk. The risk review, then, determines those areas of the project of highest risk and initiates steps necessary to develop better cost/schedule definition. Factors that affect risk are the following:

a) Project size

b) Project complexity

c) Level of technology required

Added to these are certain organization-related risk factors:

a) Working skills and competance

b) Management skills and competance

Measures typically taken to reduce risk are the following:

a) Break down the job into smaller, more measureable phases

b) Reduce scope of work

c) Employ more standard methods

d) Implement smoother work procedures

e) Implement better performance measurement procedures

f) Seek alternate responsibility assignments

APPENDIX I

GLOSSARY OF TERMS

This section is incorporated to define the terms used throughout the documentation. The following is a list of those terms and their definitions:

Account	The WBS cost category to which an activity belongs. In addition, it will normally be part of the activity's work package number which is a necessary key in identification of the activity within the network.
Activity	An identifiable task in the total project having a start and finish date and sequenced relative to other project activities by the structure of the schedule network.
CPM	Critical Path Method, a procedure for determining activity schedules based upon their individual durations and lead times and upon the organization of activity sequences within the network.
Delivery (D)	The vessel will have reached the final completion of contracted work, and will be ready to be turned over to her owner.

Dry Survey (DS)	This is the stage in production where all major steel work within a particular zone has been completed. The zone will now be ready for the start of on-board outfitting.
Dummy Link	A restraining connection between two activities. A dummy has zero duration, but may be assigned a positive or negative (overlapping) lead time between the two activities.
Duration	This is the time planned to accomplish the task.
Early Finish	Earliest possible finish date for an activity.
Early Start	Earliest possible start date for an activity.
Event	Specific point in time within the project network when activities begin and/or finish events correspond to network nodes.
Float	Same as slack time.
"I" node number	This schedule network event defines the starting point of an activity. Its identification number can be pre-determined, or be a variable of a zone or unit.
Item Number	A discrete number which uniquely identifies an activity within a given PERT-PAC Micronet. The chosen numbers should be sequential within the Micronet.
"I" node number	This schedule network event defines the ending point of an activity. Its identification number can also be pre-determined, or be a variable of the zone or unit.
Late Finish	Latest possible finish date for an activity after all slack time has been used; any further slippage in finishing the activity will slip the overall project completion date.
Lead Time	The extra amount of time expected to be required after a preceding activity, or set of activities, has been completed before a succeeding activity can begin. A negative lead time represents a succeeding activity that can start before a preceding activity has been completed.

Micronet	A small portion of the vessel's network which usually is incorporated into the network repeatedly. The Micronet Library, which is a part of the PERT-PAC scheduling system, is used to maintain all the vessel's Micronets.
Module	The placement of equipment and its related systems together on a machine foundation (seat) prior to its installation on-unit or on-board.
Node	A network event representing a point in time when activities begin and/or finish.
On-board Outfit	Installation of fittings, without prior assembly, on-board the vessel. This method of outfitting is normally the most expensive in terms of worker convenience, access to work, access to tools and materials, and overhead for crews' transfers to and from job.
On-unit P/O	A method of pre-outfitting which allows equipment to be assembled and installed as a unit, in the shop, independently of the vessel structure. This procedure normally enhances safety and reduces manhours and work durations over other methods of outfitting, such as on-board outfitting. On-unit pre-outfitting may also refer to all the assembly of outfit modules.
Panels	Sub-divisions of units being processed through the assembly shop.
PERT	Program Evaluation and Review Technique that utilizes CPM procedures for computing activity schedules. PERT also calculates odds on any given date actually happening using a very simple statistical computation upon three (3) separate manually derived estimates of duration for each network activity: most likely, most optimistic and most pessimistic. PERT-PAC, contrary to its name, does not perform this probable odds analysis.
Pre-outfitting	Outfitting on steel assemblies as opposed to on-board the vessel.

Slack Time	The scheduled leeway which allows flexibility in the duration of an activity without adversely affecting the schedule of any other activity, or the completion date for the overall project.
Sub-assembly	A definable unit of product to be delivered.
Sub-net	An isolated collection of activities within an overall larger network.
Units	Hull structural assemblies composed of several panels and being erected as a whole on the ways.
Variable	When the "I" and "J" node numbers are not fully defined, they will be a variable of the zone or unit. Their numbers will be automatically generated by the system, based on the input data.
WBS	Work Breakdown Structure or chart of acounts, usually representing each engineered ship system and hull structure, plus ship construction support and management services.
Work Centre	An area of the yard or ship where an activity (work package) is to be performed. It is a necessary key in the identification of an activity within the network.
Work Package	A distinct and definable unit of work that can be started and completed without significant interruption under the direction of a single work centre.
Zone	An optional breakdown of a project's product definition useful for added cost/schedule control purposes.
Zone Complete (ZC)	This is the stage in production where all steel work, pre-outfit work, and on-board outfit work has been completed.
Zone Ready (ZR)	This event indicates that the zone is ready for the start of on-board outfitting.

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