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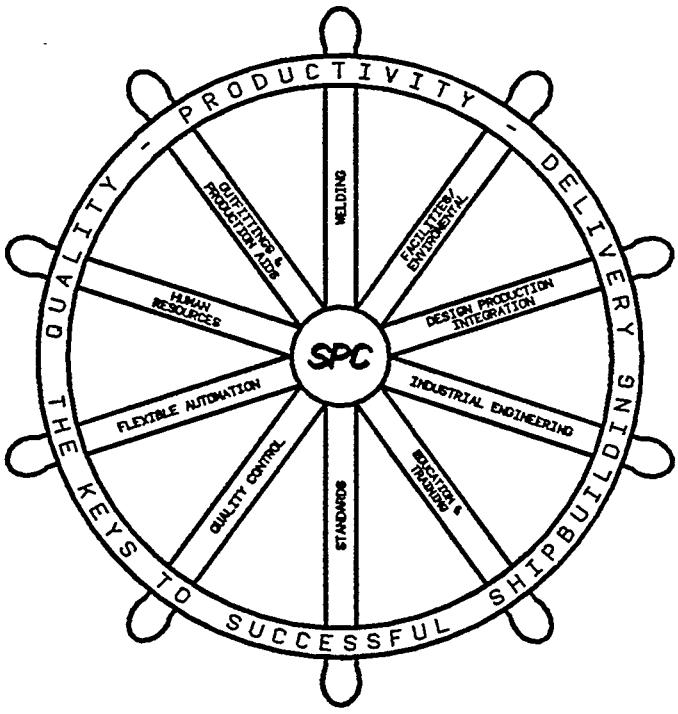

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Network Scheduling Development in an MRP II Environment

Richard J. Neumann (M)-National Steel and Shipbuilding Company

ABSTRACT

Large manufacturing industries have been able to successfully reduce cost and cycle time through the use of Manufacturing Resource Planning (MRP II) systems and principles to control material flow and the production process. Ship construction can not be neatly classified as a manufacturing process. The complex relationships involved with the installation and activation of ship's systems more closely resembles a construction operation. Work of this type has traditionally been controlled through an activity based network scheduling system. However, MRP 11 principles offer numerous benefits for the shipbuilding industry. This paper discusses an approach to planning, scheduling, and management of ship construction which takes advantage of benefits from both approaches. By using both network scheduling and MRP II in an integrated scheduling system, a shipyard will be better able to plan and execute the ship construction process.

OBJECTIVE

An effective planning and control process for a shipyard will meet the objectives stated below

To the greatest extent possible, provide a consistent work approach (common strategy) to take advantage of the learning process,

Increase producibility by increasing the interaction between engineering and planning functions early on in the design process,

Provide clear, consistent requirements to materials, engineering, and production departments, reflecting the shipbuilding strategy,

Provide an accurate and concise analysis of project status to help determine what actions need to be taken to support the ship's completion milestones,

- Provide straightforward impact analysis and rescheduling as deviations from the initial plan occur,
- Provide tools for credible shop floor control which reflect the build strategy, and
- Provide feedback and monitor performance.

With these objectives in mind, an effective method for scheduling production in a shipyard environment will be presented.

OVERVIEW

To meet the stated objectives, project planning and scheduling should take a top down approach, starting with general goals and objectives and working towards progressively more detail. As this greater level of detail is developed, it must support the goals and objectives upon which it is based. Taking this top down approach will allow for a more consistent approach throughout the production process. Goals and objectives developed early in the ship design/construction process provide a common basis to which all groups can work. This common basis makes it easier for production, planning, and engineering to work together in developing producible designs and effective build strategies.

The two scheduling approaches most commonly used today are the network schedule and Manufacturing Resource Planning (MRP II). Both approaches present a strategy in the form of a plan. A plan is a simulation of what is needed to reach a goal (e.g. deliver a ship). Each approach has benefits.

The network approach permits better scheduling and control of key events. A network will show the various relationships activities have with one another.

These relationships make the network an excellent tool for assessing the impact of change and reporting activity status. MRP II provides automated schedule generation to the extent that the product structure is defined. MRP II uses a closed loop that provides control over execution of the plan and feedback as events occur to monitor performance.

Design-to-order project shops and construction operations have traditionally been controlled through an activity-based network scheduling system. Mass production manufacturing operations have been able to successfully reduce costs and cycle time through the use of MRP II to control material flow and the production process. The shipbuilding process can not be neatly classified as either a project type construction operation or a manufacturing operation. Shipbuilding contains elements of each. Fabrication of the many components that make up the ship (e.g. piping, vent, machinery foundations) may be viewed as a manufacturing process. Joining of the hull and the installation and activation of the ship's systems more closely resembles a construction operation.

The solution to the dilemma of which scheduling approach to use is a simple one: use both. In this way, the shipbuilding process may take advantage of benefits from both a network and an MRP II scheduling approach.

High-level schedules are developed via a network. The network consists of interrelated tasks that are defined at the appropriate level to drive demand in the MRP II system. Detailed definition of individual tasks is not a network but a materials-based MRP II plan for that master schedule item.

By using a network to drive the master schedule items of an MRP II system, the benefits of both approaches are realized. The network controls the key events, reports status at a high level, assesses the impact of change, and allows for effective rescheduling as deviation occurs. The MRP II system serves as the tool that controls shop floor execution of the plan. The MRP II system provides feedback as events occur in order to monitor performance. The question now becomes: to maximize the benefits of both network and MRP II scheduling approaches, at what level does one define the network which will serve as the top of the MRP II bill? The remainder of this paper will address the development of network schedules and how they are used to drive an MRP II system.

GLOSSARY

The following definitions are provided to clarify usage within this paper. They are not meant to imply an industry standard.

UNIT: A structural assembly which is outfitted and erected on a ship or joined with other units and then erected on a ship.

MAKE-UPS: Small sections of pipe and vent that cross erection butts of units and therefore cannot be installed until the unit is joined to a ship's structure.

BLUE-SKY ITEM: Machinery and material that is loaded into a ship before the unit closing out clear access is erected. This is illustrated in Figure 1.

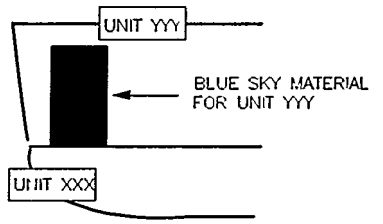


Figure 1: Blue-sky item definiton.

GEOGRAPHIC ZONE: A geographic volume on-board a ship&compassing a logical grouping of work such as a tank or cargo hold.

FUNCTIONAL ZONE: A logical grouping of work on-board a ship that may pass through several geographic zones such as a main cable pull or shafting system.

SCHEDULE DEVELOPMENT METHODOLOGY

In an MRP II system, demand is driven by items at the top of the bill of material. These are the MRP II master schedule items. Defining the master schedule item as the completed ship and structuring the entire build process beneath this activity is not a practical or effective solution. Intermediate milestones would be difficult to evaluate, progress would be difficult to track, and the impact of delays and change would be difficult to assess. The ship

production process should instead be broken down into interim products, which in turn can be broken down into a series of activities or tasks. The tasks required to create the interim products are used as the MRP II master schedule item. All material required to build the vessel is structured beneath the appropriate master schedule item. For shipbuilding, the interim products may be divided into two categories: ground assembly and outfit (GA&O) master schedule items, and on-board master schedule items.

GA&O encompasses steel fabrication, assembly, joining, and erection of units along with shop fabrication and installation of items which are installed prior to erection, and any testing performed prior to erection. On-board master schedule items include the fabrication and installation of make-ups and blue-sky items, as well as remaining work and tests performed on-board the ship.

Definition and scheduling of the activities which comprise the top of the MRP II bills is part of a sequential planning activity process. The planning process is a top-down approach starting at a high "conceptual" level with major milestones and production goals based upon these milestones. These milestones and production goals are used as a basis to develop GA&O and on-board build strategies. The strategies, along with the erection schedule, ship's completion schedule, and process lane strategies are the basis for the development of master schedule networks. These networks drive the MRP II system. An overview of planning and scheduling document development is shown in Figure 2.

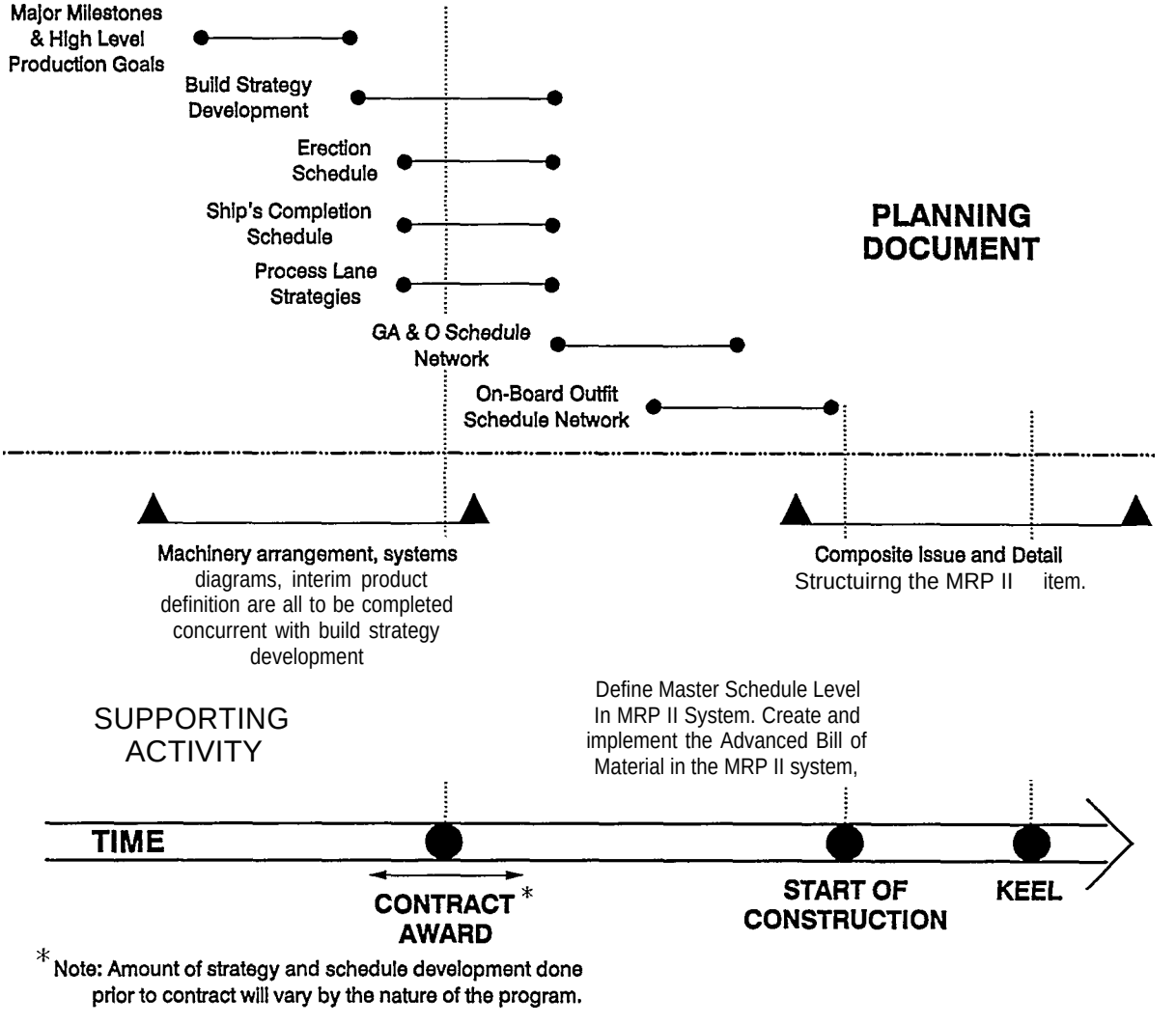


Figure 2 Planning activity timeline when planning and scheduling documents are to be developed relative to key milestones and supporting activities.

HIGH LEVEL STRATEGIES AND SCHEDULES

Major milestone schedules and high level production goals must be developed and agreed to by all concerned groups before further planning can proceed. Major milestone schedules define key events such as contract award, start of construction, keel, launch, trials, and delivery. The schedule is based upon key business plans, contract requirements, and factors such as expected yard manning and workload. High level production goals address the amount of work to be done on the ground and the amount performed on-board. The goals also show when certain parta of the ship are to be built relative to the major milestones. A sample of production goals for a cargo vessel is shown in Table I.

PRODUCTION GOALS						
	GROUND ASSEMBLY & OUTFIT			ON-BOARD		
	ASSEMBLY AREA	MACHRY UNITIZATION AREA	PRE-OUTFIT AREA	COMPL BY STERN RELEASE	COMPL BY LAUNCH	POST IAUNCH
MACHRY SPACES	Innerbottom piping, menholes end ladders compl.	Machinery cores (includlng all equip except ME) complete, hydrood, and flushed.	Sea chests complete	Cores Iand X wks prior to release, install make-ups and remove temp. staging. core make-up compl X wks after relesae.	Power & automation compl, ME connect make-up X wks after launch. Mske-ups w/caslng compl X wks after launch.	Turn over ME X wks after launch
CARGO DECKS	Beck-up structure for deck equip and foundations Installed.	Pipe tacks including machry, valves, elec, air,fire & foam. Piping hydrood, flushed and legged.	Fully outfitted except for make-up pieces at block breaks. Install submerged pumps.	Mske-ups between aft tanks complete within X wks after release.	Make-ups between fwd tanks complete within X wks aftar launch. Submerged pumps Installed.	Deck outfit compl X wks after launch.
DECK HOUSE	Large dla piping, fnds, vent spools and curtain plates.	Fen mom units complete, hydroed, and flushed.	Outfit compl except for mske-up to machinery space.		Distibution systems compl, equipment hooked-up, Joiner work compl. X wks after launch.	Flooring, paint end finish work compl X wks after launch.
CARGO & BALLAST TANKS	Outfit compl except submerged pumps and vent Iadders.		Install valve operator reach rods.		Cargo and ballast system complete.	Tank outfit compl X wks after launch.
STERN	Tank piping including stem tube LO, ladders, end rnenholes.	Steering gear unit complete, hydroed and flushed.	Mooring equip and fittings install. Hot work on deck compl. Ruddertrunk bored,	Compl stem tube within X wks after release.	Final align shaft and installation compl X wks after launch.	Aft deck outfit complete X wks after launch.
BOW	Belfast piping, ladders, menholes installed.		Fwd stores and paint locker compl. All deck outfit including mooring and anchor handling compl.		Make-up to distribution system an deck complete X wks after launch	Fwd deck outfit complete X wks after launch.

Table 1: Production goals for a sample cargo vessel to be used as a basis for more detailed schedule development.

Upon approval of the major milestones and production goals, build strategies are developed for both the GA&O and on-board areas. For GA&O, a vessel is divided into a series of units that allow for efficient erection and the maximum extent of pre-outfit given a yard's facility constraints. Once the u'nits have been defined, strategy sheets may be developed based upon machinery arrangements, system diagrams, right-of-way strategies, and production goals. A good high level strategy may be developed before composite drawings are issued. The sheets describe which items are to be installed and tested at each task within the GA&O process. A sample strategy sheet format is shown in Table II.

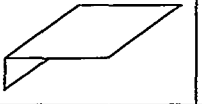
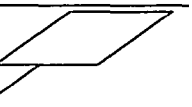
INTEGRATED ASSEMBLY/ OUTFIT STRAT BY UNIT TYPE				UNIT TYPE: CARGO HOLD	
					
TASK / PRODUCT TYPE	ASSEMBLY	PRE-BLAST INVERTED OUTFIT	PRE-BLAST UPRIGHT OUTFIT	BLAST & PAINT	POST-BLAST OUTFIT
STEEL	*All structure and* related items except for topside work.		Weld-out topside seam.		
PIPE & MACHINERY	Drain wells. Deck penetrations.	Sprinkler piping.			Fire station sensor tubing.
VENTILATION	Vent spools.	Spiral duct.			Cable actuators and pull cables.
ELECTRICAL	Light standoffs. Waterway collars.	Cable ways.	Connection boxes.		Lights, sound powered telephones, local cable.
METAL OUTFIT		Overhead storage rack tracks.	Elevator door stowage. Truck gaurds.		
BLAST & PAINT		*Paint in-way-of.*	*Paint in-way-of.*	Sandblast & paint unit.	
PRODUCTION SERVICES		Layout and shoot insulation pins.			Install scaffold for use on-board.
SUB-CONTRACTOR					Insulate.
TEST		Sprinkler local hydro.			

Table II: Ground assembly and outfit strategy sheet for a cargo hold unit.

For on-board, a vessel is divided into geographic and fictional zones which allow for the logical grouping of tasks. Once these zones are defined, on-board strategy sheets are developed. These strategies encompass the remaining work that was not defined by the GA&O strategy sheeta. On-board strategies are developed in conjunction with the GA&O strategies to guarantee that work is assigned to meet the high level production goals. A sample on-board strategy sheet is shown in Table III.

ON-BOARD STRATEGY BY ZONE TYPE					ZONE TYPE: CARGO HOLD		
TASK / PRODUCT TYPE	MAKE-UP FNDS & HOT WORK BY UNIT	STORAGE RACK TRACK INSTALL ON DECK	DECK COVERING	ELEC LOCAL PULL AND HOOK-UP	PICK-UP PIPE VENT, TEST	PAINT-OUT ZONE	Z PHASE ZONE
STEEL					Air test access trunk.		
PIPE & MACHINERY	Make-up pieces. Reach reds.						Sensor tubing.
VENTILATION	Make-up pieces. Thermo bulbs. Vent plenums.						
ELECTRICAL				Pull remaining local cable. Hook-up main and load cable.			
METAL OUTFIT	Waterway coamings.	Complete lower door track. install deck tracks.	install clips.				
BLAST & PAINT	Paint IWO exclusion plates end *vent*	Final paint sumps and close.	Paint IWO deck severing.			FM paint *zone.*	Touch-up final paint
PRODUCTION SERVICES							Remove temp services.
SUB - CONTRACTOR	Insulate IWO as required.		Pour deck covering				
TEST		Check point track allignment					

Table III: On-board strategy sheet for a cargo hold zone,

The erection schedule defines the dates on which units are erected on a ship. This schedule addresses not only steel concerns such as reasonable erection rates which support available manpower and structural integrity, but also outfitting concerns such as loading and installation of major equipment, stem release, and the schedule's ability to support the ship's completion milestones. A sample of an erection schedule is shown in Figure 3.

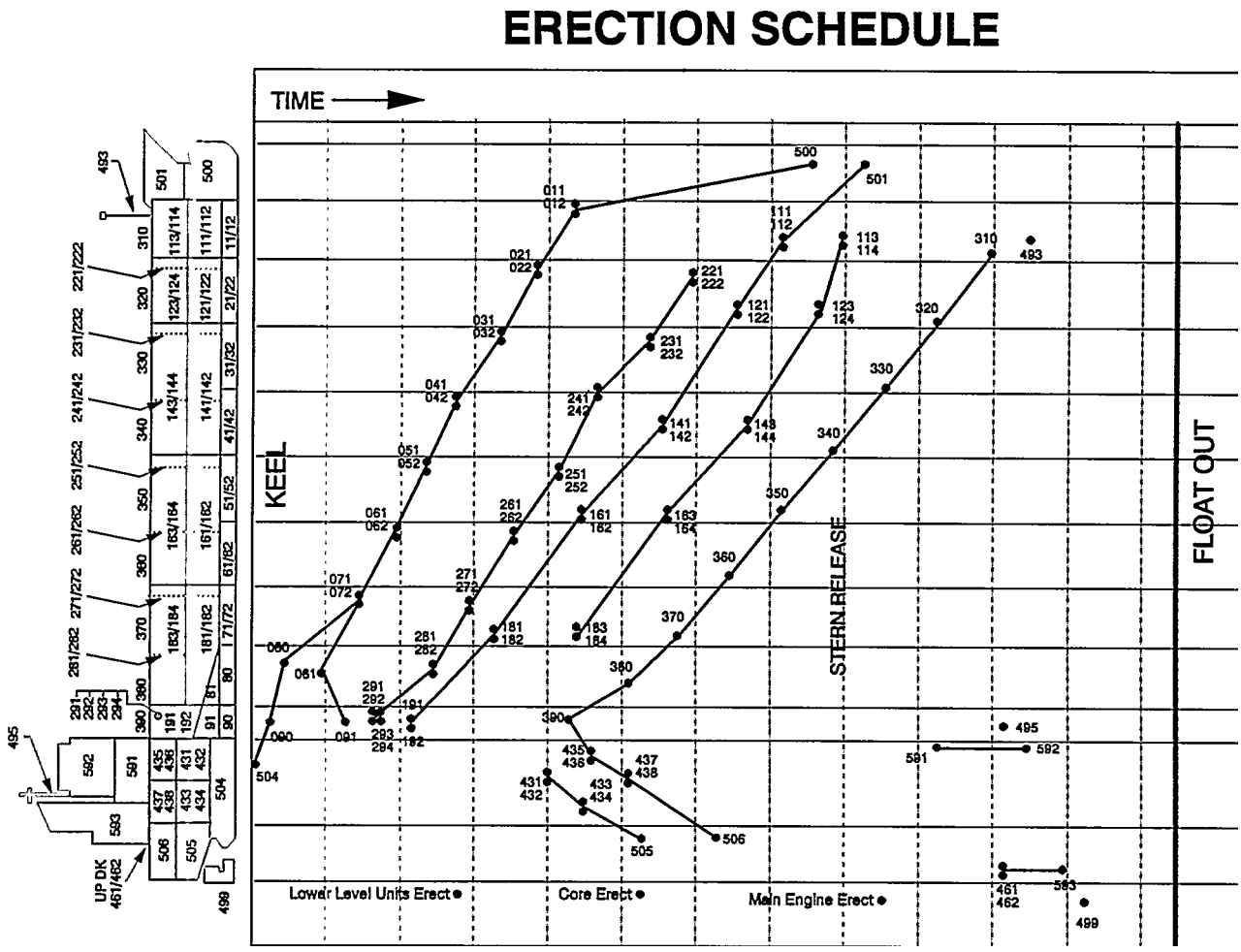


Figure 3: Erection schedule for a sampe cargo vessel defining the dates units are erected to the ship.

The ship's completion schedule defines the dates that high level activities, which are key points in the ship construction process, occur. The completion schedule consists of three types of activities:

- Area close-outs such as forward tanks closed, cargo spaces closed,

Key events such as stern release, launch, light-Off SSDG'S, and

- Major system tests/trials such as integrated plant testing, sea trials.

A sample ship's completion schedule is shown in Table lV.

Process lane strategies define repetitive work stations in the GA&O area. If multiple items are going to be sequenced through a single location, the second item cannot be started until the first item is complete. Virtual process lanes may be established on-board. A virtual process lane consists of a dedicated work team assigned to do one task in several areas throughout the ship such as the installation of all tank level indicators. Since there is only one team, the tank level indicators in one area cannot be installed until the task has been completed in the previous area. These strategies must be defined so that the proper relationships may be established in the master schedule netvorks. A sample of a process lane strategy is shown in Figure 4.

SHIP'S COMPLETION SCHEDULE

MILESTONE ACTTIVITY		COMPLETION
AREA CLOSE OUTS -	FO Storage/Slop	Launch - X wks
	Ballast tanks, Holds 2-8	Launch - X wks
	ForepeakTank	Launch - X wks
	Casing/Stack	Launch - X wks
	Main/B/C Decks	Launch - X wks
	Bridge	launch - X wks
	Bow(anchor handling, chain Ikr, stores)	Launch - X wire
	Stern(deck machinery)	Launch - X wks
	Machinery Spaces	Delivery - X wire
KEY EVENTS -	Soc	
	Keel	SOC + X wks
	Stern Release	Keel + X wire
	Launch	Keel + X wire
	Epoxy Stern Tube	Launch - X wire
	Ballast Sys Aft of Forepeak Compl	Launch - X wks
	ME Connection Made-up, Engine Chocked	Launch + X wire
	Make-Up to Casing Compl	Launch + X wks
	Deckhouse Distrib Systems Compl	Launch + X wks
	Final Align Shaft	Launch + X wire
	ME Light Off	Dock Trials - X wks
	SSDG Light Off	Dock Trials - X wks
	Restore Switchboard	Dock Trials - X wire
MAJOR SYTEM - TEST/TRIALS	Builders Trials	Delivery -X wire
	Dock Trials	Builders Trials - X wks
	integrated Plant Testing	DockTrials - X wks
	Main Engine Tact	Dock Trials - X wire
	Main Engine Aux. System Test	Dock Trials - X wks
	Generator Load Test/Parallel Test	Dock Trials - X wire
	SSDG Aux System Test	Dock Trials - X wire

Table IV: Ship's completion schedule for a sample cargo vessel,

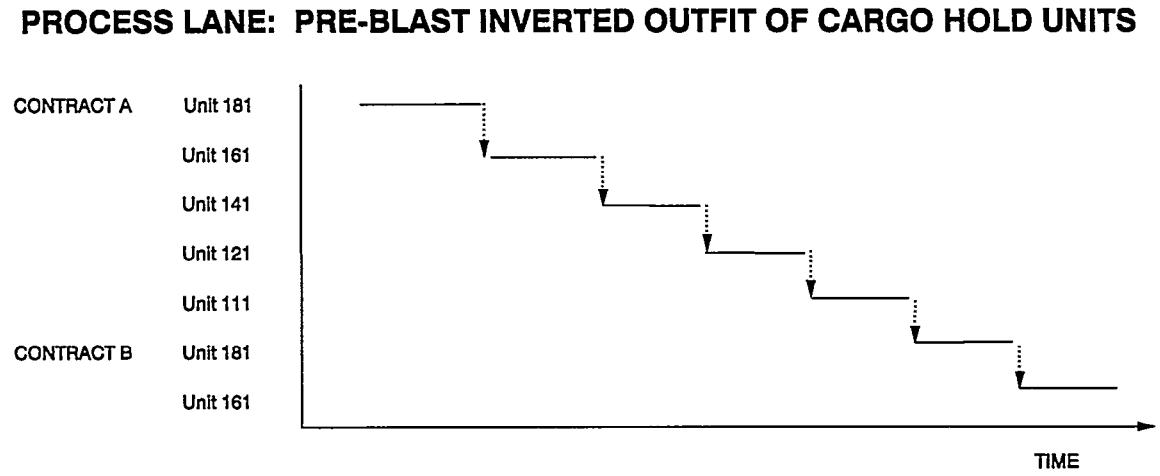


Figure 4 Process lane strategy sheet for pre-blast inverted outfit of cargo hold units.

GA&O MASTER SCHEDULE ACTIVITY NETWORK

The MRP II master schedule items for ground assembly and outfit are defined at the unit task level as shown on the GA&O strategy sheets. These items are the activities which define the master schedule network. The activities modeled by the netvork include assembly of units along with major sub-assemblies. Pre-outfitting may be modeled as a single or multiple activity depending upon the complexity of the unit. Unit erections (as taken from the erection schedule) serve as back-end constraints for the GA&O master schedule activity network. The network defines intra-unit relationships from one activity to another. The network also defines inter-unit relationships as defined by the process lane strategies. A portion of the master schedule network defining a typical unit is shown in Figure 5.

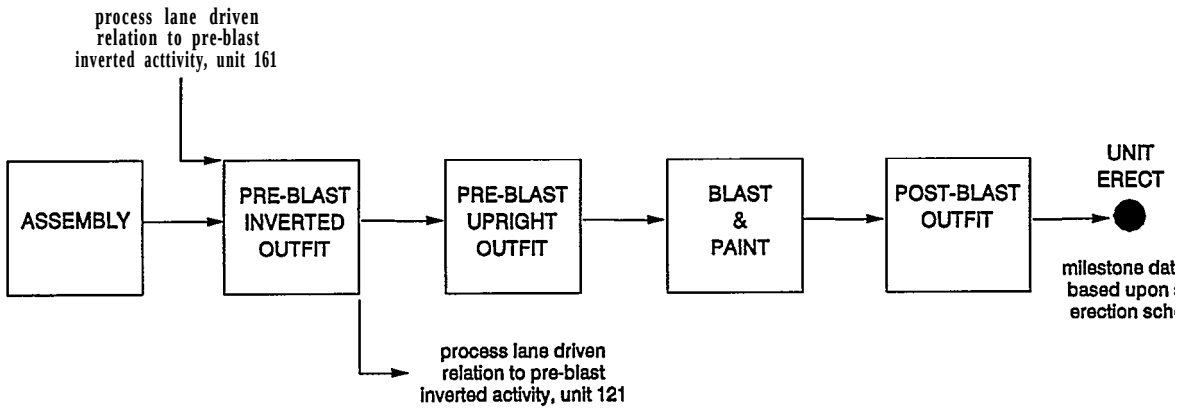


Figure 5 Ground assembly and outfit master schedule network of cargo hold unit 141 based upon the GA&O strategy sheet shown in Table II, and the process lane strategy sheet shown in Figure **4.**

ON-BOARD MASTER SCHEDULE ACTIVITY NETWORK

The MRP II master schedule items for on-board work are defined at the geographic/functional zone task levels, as shown on the on-board strategy sheets. These items are the activities which define the master schedule network. Work defined by the network picks up where the GA&O network leaves off and carries through to completion. The front-end constraints of this network are the unit erections as defined by the erection schedule. The back-end of the network is constrained by the events defined in the ship's completion schedule. The network defines intra-zone relatioosbips as well as the inter-zone relationships between tasks of different zones. A portion of the master schedule network defining a typical zone is shown in Figure 6.

MRP II SYSTEM STRUCTURING

As stated earlier, the activities defined in the master schedule networks are the master schedule parts which reside at the top of MIW II's production bill. All installation and fabrication are structured beneath the master schedule part in MRP II. Definition of these master schedule parts can be done based upon machinery arrangements, systems diagrams and right of way strategies. Detailed structuring of material installation and fabrication beneath these items is done based upon the composite drawings. Structuring for a typical unit is shown in Figure 7 and for a typical zone is shown in Figure 8.

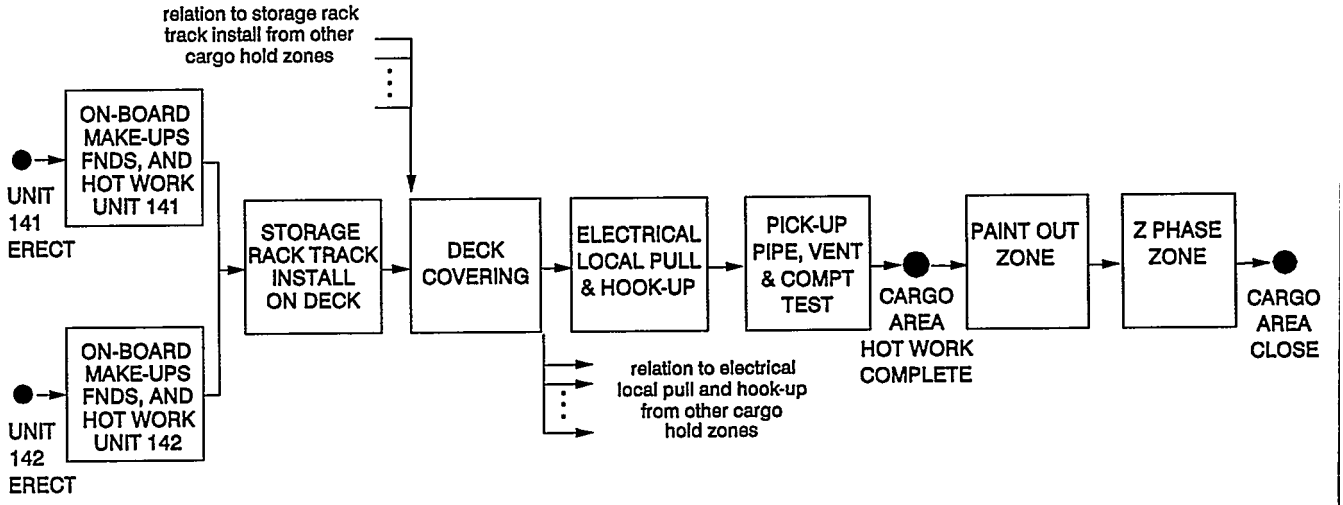


Figure 6: On-board master schedule network of cargo hold zone 1233 based on the on-board strategy sheet shown in Table III.

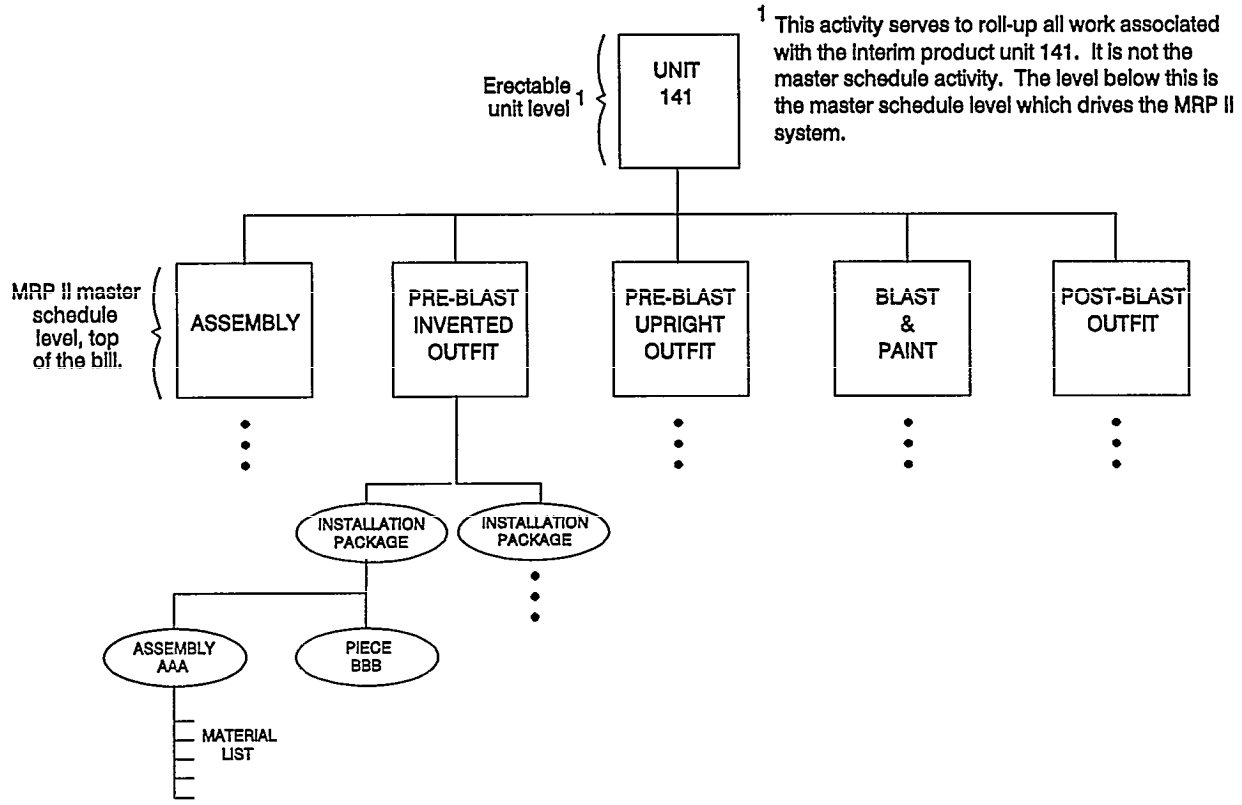


Figure 7: MRP II structuring for sample unit 141 based upon the master schedule activity network shown in Figure 5.

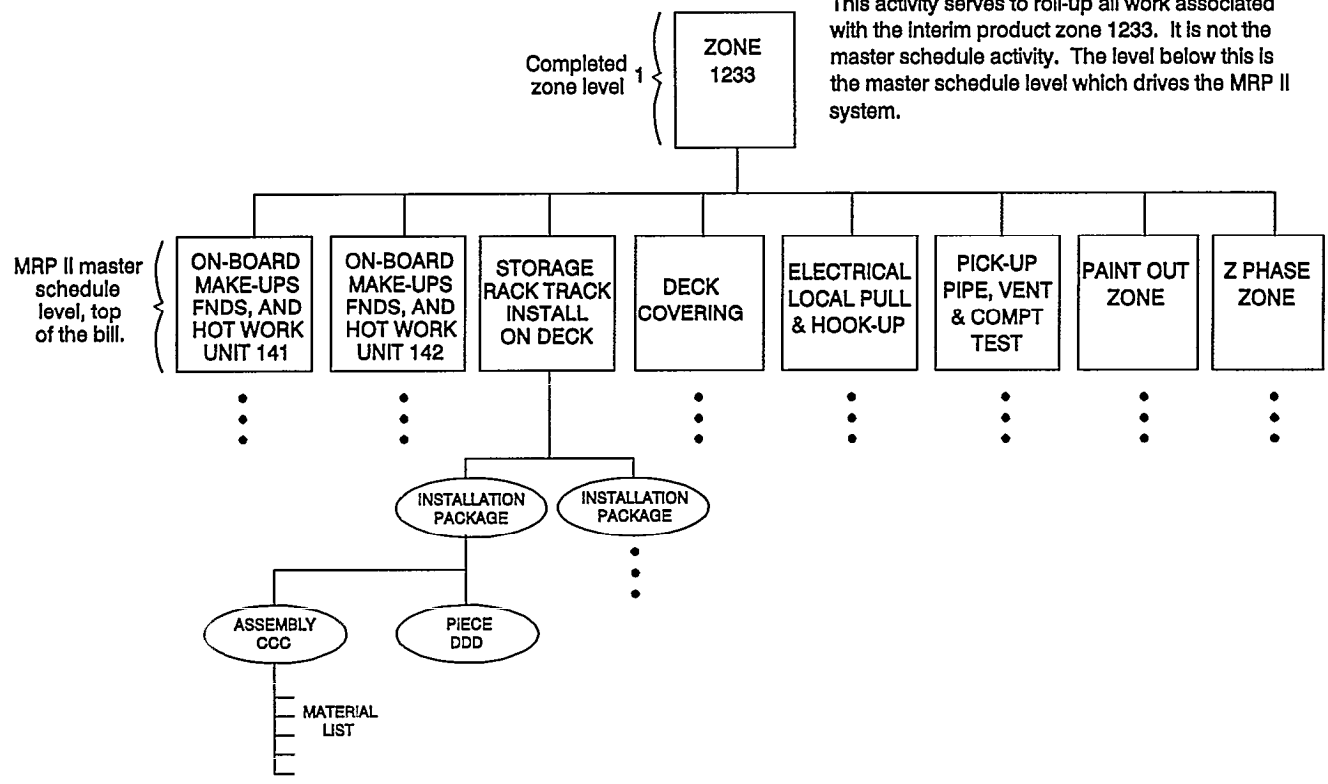


Figure 8: MRP II structuring for sample zone 1233 based upon the master schedule activity network shown in Figure 6.

SYSTEM USAGE

The master level scheduling network and the MRP II production control system serve different roles. These two systems must combine to serve material, production, and reporting needs. The combined systems must generate and update both high level and detailed schedules so as to provide production control. They must also serve to show material requirements and provide material control. The systems must facilitate internal and external reporting as well as allow for manpower and facility utilization planning. The functions performed by each system are shown in Table V.

To effectively perform these interrelated tasks, the systems must communicate with one another, and reflect a common strategy. The communication between these systems is illustrated in Figure 9. Dates generated by the master schedule activity network are fed into the top of the bill as "need dates" for the MRP II system. The MRP II system uses these dates in conjunction with the structured bill and process plan to create the production and material control schedule which drives shop floor execution to the plan. As work is accomplished, progress is entered into the MRP II system. Progress information is passed back to the master schedule activity network and the network is updated.

	MASTER SCHEDULE LEVEL ACTIVITIES	DETAILED PRODUCTION SCHEDULE	MANNING PLANS	MATERIAL REQUIREMENTS	PROGRESSING/ UPDATING	PRODUCTION CONTROL REPORTS
MASTER LEVEL SCHEDULING NETWORK	Created by network based upon build strategy and resource leveling.	———	Produced for key production areas as part of master schedule development and leveling.	Initiates procurement for selected long lead time items (eg. main engines, SSDG's.)	Progressed regularly so that realistic master schedules may be maintained.	Master schedules with regular updates.
MRP II	Reflects as top of bill.	Created in MRP II as an explosion of the structured bill.	———	Serves as material procurment/ control system.	Updated based upon changes to the master production schedule.	Dispatch sheets, work orders with detailed work instructions, and shop floor control paper.

Table V: Matrix showing tasks performed by the network and MRP II systems.

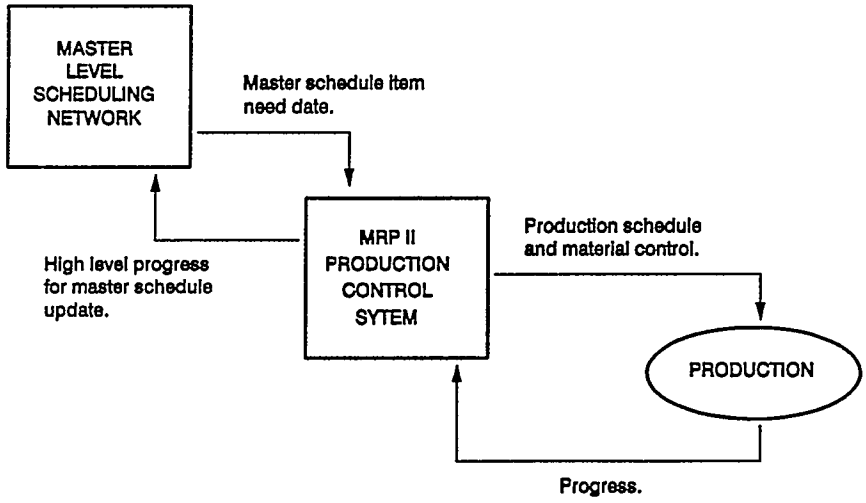


Figure 9: Communication between the network system, MRP II system, and production.

CONCLUSION

This presentation has explored two approaches to schedule development: the network schedule and the MRP II schedule. In the shipbuilding industry both approaches have a place. The network provides top level aggregate production planning, even if the supporting detail is not yet designed. This allows for planning and scheduling of activities outside of production. Indirect functions such as engineering, QA, and procurement of long lead time material can be controlled by network scheduling. The network is used to report status at a high level, assess the impact of change, and reschedule as deviation occurs. The network is the master production schedule used by MRP II. To the extent the product structure is defined, MRP II provides automatic schedule generation based upon the master production schedule. MRP II is the tool for material and production control. The network schedule and MRP II are both powerful tools. By using these tools together, a shipyard will be better able to plan and execute the ship construction process.