CAPT Jonathan Iverson, USN (Ret.)
CDR Kent Kettell, USN (Ret.)
Sanjeev Gupta, Realization Technologies

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Improving Fleet Operational Availability with Dynamic Execution Intelligence for Shipyard Projects

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US Navy's current fleet of 273 is the smallest since 1916. In about a decade, our fleet of attack submarines will shrink, reflecting decisions taken in calmer times. Even if new boats are built as fast as possible, the number will fall from 52 now to 42 or so by 2028. Meanwhile on time delivery of maintenance is also an issue, further affecting fleet operational availability. For example, 60%-70% of the submarines in maintenance are typically behind schedule.

The Navy has a goal of rebuilding our strength to 355 ships by 2050 by building new ships and extending the life of current fleet, but China's combat fleet will reach 415 ships by 2030. As ADM John Richardson, the Chief of Naval Operations, told a congressional panel in March that China's rise and a resurgent Russia meant America no longer enjoys a monopoly in sea power or sea control.

In addition to ascendancy of China and resurgence of Russia, there is also a proliferation of threats from smaller state and non-state players. These dangers are building up at the same time as trade and other dependencies among different regions are increasing. Therefore, the US Navy has a more important role than ever in assuring the world's peace and prosperity.

Some argue that we can hit our 355-ship target sooner by refitting old vessels, but that requires executing currently planned Availabilities faster and more efficiently. Not to mention the mounting pressure on readiness of current fleet, especially after a recent bad run of accidents, and the constant struggle to deliver Availabilities on time.

This paper outlines a scheduling method that can reduce Turnaround Times (TAT) for Availabilities by 15% to 20%, and free up enough capacity to execute one-and-a-half more Availabilities[1] every year[2]. It is already being used successfully in NAVAIR for aircraft MRO as well as in the industry for other complex and multi-year projects. The Naval Shipyards can use additional capacity to make a significant impact on Fleet Operational Availability by improving on time delivery, reducing deferred maintenance, and retrofitting old vessels.

History of Shipyard Improvement Initiatives

Public shipyards in NAVSEA have much experience in reviewing and implementing new quality and process improvement methods. Impressive improvements in quality and productivity have been achieved in the last thirty years by adopting new ideas, methods and processes.

For example, prior to NAVSEA's Quality and Performance Improvement Conference in June 2000, shipyard managers were taught systematic approaches to problem solving and decision making (Kepner & Tregoe, 1965) and principles for improving quality and productivity (Crosby, 1979; Deming, 1986; Juran, 1989). Total Quality Management, the High-Performance Organization, and managing according to the Baldridge National Award Criteria using the right metrics to keep score (Brown, 1996) were part of Shipyard management and operations as Advanced Industrial Management was implemented. There was also a shift from MIL-Q-9858 to an ISO 9000-like quality program and reengineering the corporation (Hammer & Champy, 1993) prior to the Quality and Performance Improvement Conference. After the conference the Shipyards took on Lean, Six-sigma and Theory of Constraints to continue the improvement efforts. Gardner lead initiatives in Lean and Six-sigma while CAPT Joseph Bradley and CAPT Jonathan Iverson championed Theory of Constraints at the Pearl Harbor Naval Shipyard and Intermediate Maintenance Facility. These led up to the Naval Shipyard Transformation Program of 2005.

The question now is, "What next?" How can the Naval Shipyards significantly reduce turnaround times by 15% to 20% to make an impact on Fleet Operational Availability? What is the leverage point for realizing these reductions in a few years rather than a decade or two?

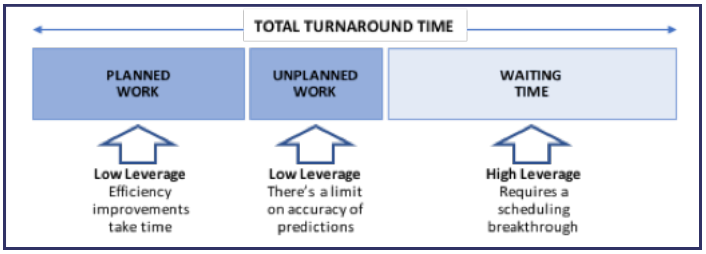
[1] A "normalized" availability is the size of a typical PIA on a CVN and a typical DMP on an SSN.

[2] Based on man-day, cost, and turnaround time data for all eighty-two (82) Availabilities completed in the four Naval Shipyards from October 1, 2001 through September 30, 2009 (eight years):

- PSNS & IMF: 24 Availabilities completed on 9 CVNs, 4 SSGNs, 1 SSBN, 9 SSNs, and 1 AS
- NNSY: 23 Availabilities completed on 8 CVNs, 2 SSGNs, 1 SSBNs, 10 SSNs, 1 MTS, and 1 LHD
- PHNS & IMF: 18 Availabilities completed on SSNs
- PNS: 17 Availabilities completed on SSNs

Finding the Leverage Point: The Opportunity Lies in Synchronization of Schedules

There are many valid arguments as to why shipyard projects cannot be done faster: uncertainties and increasing complexity of maintenance; a shrinking supply base; the natural progression of promotions and retirements; and the cycles of workload peaks and valleys; etc.



Yet, it is also true is that planned and unplanned work are only 50%-60% of the total turnaround time for an availability (or any project for that matter). The remaining 40%-50% of the turnaround time is wasted in waiting: work waiting for resources; resources waiting for work, tools, equipment, engineering dispositions, paperwork, decisions etc. there are enough quantitative and qualitative data to indicate that synchronization of schedules is a major area of opportunity to reduce availability turnaround times. For example:

- Work flows in bow waves, both within and across availabilities. Earned Value (EV) measures are good at the start of the project, even better than the norm, but decline over time. This points to a deficiency in how resources and work are balanced.
- Mechanics on the deck plate work only for 4 to 5 hours of an 8-hour workday; rest of their time is spent waiting or scurrying around.
- Project plans are ignored on the frontline because unknowns and delays render them obsolete before projects even begin. In fact, schedulers are always playing catch up with what has already happened rather than guiding what should happen.
- Given the complexity of shipyard operations, most of these decisions are based on local rather than holistic considerations; that's why priorities continually shift: what was urgent one day goes on the backburner a few days later.
- Supervisors, project managers and senior leadership spend as much time and attention on resource and work schedules as on technical issues.

We appreciate that synchronization of schedules in large projects, or multiple projects with shared resources, is not easy. Even if all the work scope were certain and time and resources required to perform tasks were deterministic, scheduling of work for a few thousand resources would be a very complex problem (an NP-hard problem in mathematics). Once you inject delays, technical problems, uncertainties of work scope and uncertainties related to resources, the scheduling problem becomes intractable.

At the same time, there is now sufficient evidence from other MRO environments and large projects that the problem can be solved and performance can be substantially improved.

CASE 1: US Navy F-18 Depot Maintenance

Performance Metric	Before	After
Project Completions	6/year	11/year
Group Readiness or Fleet Availability	36 aircraft on station	17 aircraft on station

CASE 2: Delta Engine Maintenance

Performance Metric	Before	After
Project Completions	476 engines per year	586 engines per year
Project Cycle Time or Duration	30 to 90 days, mean 46 days	15 to 65 days, mean 32 days

CASE 3: US Navy Shipyard Pearl Harbor

Performance Metric	Before	After
On Time Completions	Less than 60%	Over 95%
Cost per job	$5,043	$3,355 ($9M savings in first yr)

CASE 4: US Navy Fleet Readiness Center, Cherry Point

Performance Metric	Before	After
Hours of Work Performed	160,500 hours per month	178,750 hours per month
Labor Rate	Mean Labor Rate of $112/hr	Mean Labor Rate of $94/hr

CASE 5: US Air Force C-5 Depot Maintenance

Performance Metric	Before	After
Project Cycle Time or Duration	240 days	160 days
Group Readiness or Availability	13 aircraft on station	7 aircraft on station (6 returned)

Untying the Gordian Knot of Scheduling: Differentiate Planning from Execution

Getting all the execution details right at the time of planning is not only impossible but also unnecessary. Schedules created in planning serve a different purpose than schedules required during execution, and we don't need detailed execution schedules to fulfill planning objectives. This simple insight is the key to solving the scheduling problem in projects.

For example:

- Whereas the purpose of planning is to establish due-dates for key milestones, the primary concern in execution is that resources work on the right tasks at the right time. Exact start and end dates for every step in the repair process are neither practical nor required at the time of planning: approximate task durations are good enough for calculating reliable milestone due-dates.
- At the time of planning, resource managers need an aggregate forecast of resource requirements, but during execution they need to know exactly how many resources to allocate to which projects/ supervisors. Exact resource requirements with precise timing for every step in the repair process are neither possible to provide nor required; approximate resource requirements for major jobs are good enough.
- It's not enough to provision enough management reserves (time, resources and money) for unplanned work; during execution, supervisors and managers need to know where and when to spend those reserves.
- Only the synchronization at major integration points can be assured at the time of planning; day-to-day synchronization is the domain of execution schedules.

Current scheduling practices and tools require planners to try and get all the details of daily execution precisely right at the time of planning — from breakdown of work into hourly activities and specifying technical dependencies between those activities, to the exact schedules for tasks and resources. As a result:

- Plans are overly complex, with thousands of tasks and dependencies. Not only is such planning error-prone (especially the technical dependencies), but resulting plans are impossible to keep up-to-date as changes happen in execution.
- Plans are too rigid to follow in execution anyway, and supervisors simply ignore them. They make execution decisions based on limited information ("I really don't know if this will help the availability."); local optimization ("let me just keep my people busy," or "let me just maximize my Earned Value.") and even irrational considerations ("who is screaming the loudest?").
- When plans are not followed, all synchronization is lost and managers rely more on subjective judgment rather than objective measures to determine which problems are most critical to solve with their limited bandwidth.

Good project management systems for the shipyards can no longer be built just with planning logic. Execution logic is also a must; without it you end up with unusable plans and unsynchronized execution.

Details of the Solution

Untangling execution logic from planning raises an obvious question, "What data and algorithms should be used in planning versus execution?" Categorizing the uncertainties involved can help answer this question (if there were no uncertainties, we could have all the details at the time of planning and use the same logic for planning as for execution).

In general, there are two categories of uncertainties that afflict shipyard projects for which a two-part solution is required:

(1) Uncertainty of Work and Flow, Solved by Organizing Projects as 2-Tiered Workflows.

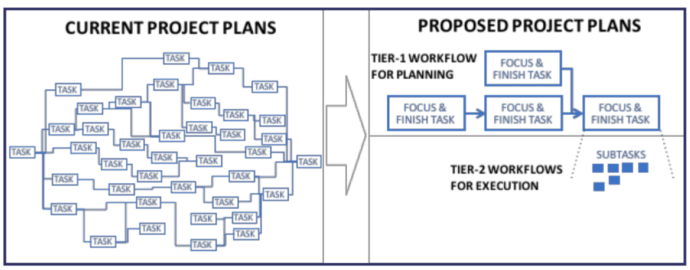
Project networks, which capture the tasks to be done and the sequence in which to do them, are constantly changing. Tasks themselves change as requirements change, additional scope is discovered after inspections and during actual repairs, and as technical issues are encountered. The sequence in which tasks are done also changes based on urgency, resource availability and individual preferences.

At the same time, there is always a certain level of granularity at which the workflow is stable. Consider tank repairs in an availability project for example. All the tanks that need to be repaired are known, and the sequence in which the tanks are repaired can be established, at the time of planning. However, the actual activities required to repair a given tank and, because of interferences, the exact sequence in which those activities will be performed need to be decided by supervisors and resources on the deck plate. Project Managers need not concern themselves with the nitty gritty details of work, only with how long the set of tanks will take to get done.

This approach can be formalized by organizing project plans into two-tiered workflows:

a. Tier-1 Workflow: the end-to-end flow of work that can be established at the time of planning and remains stable in execution. This workflow should be granular enough to establish a project's critical path and resource requirements. Additionally, tasks in this workflow should be defined to minimize waiting time and switching costs: it should be faster and more efficient for resources to "focus and finish" a given Tier-1 task before starting the next rather than getting spread thin among many Tier-1 tasks.

b. Tier-2 Workflow: the detailed flow of work within a Tier-1 task that is required for execution. Supervisors should have flexibility to define and modify this workflow based on ground reality. Moreover, it's okay if only partial or even none of the data about Tier-2 tasks is available in planning; whatever is available is good enough.



The ratio of tasks in Tier-1 workflow to the number of subtasks in Tier-2 workflows ranges between 1:20 and 1:75. For example, we have successfully modeled actual projects that are traditionally comprised of about 50,000 tasks as ~700 Tier-1 tasks and ~50,000 Tier-2 tasks; and projects that traditionally have about 1,000 tasks as ~40 Tier-1 tasks and ~1,000 Tier-2 tasks. Such simplification of project plans is significant by itself; not only does it reduces data entry errors but also makes visualization, navigation and maintenance of a project plan easy.

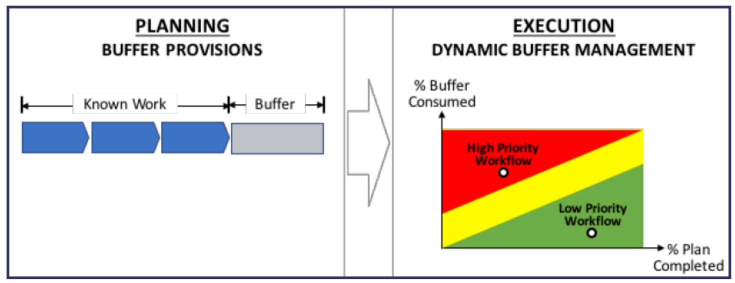
(2) Uncertainty of Timing and Resources, Handled with Dynamic Buffer Management[3]

Even though Tier-1 workflows are predictable, it is impossible to predict exactly when any Tier-1 task will be done due to uncertainty about how much time and effort it takes to complete it, when resources will be available, when parts and supplies will be received, etc. Therefore:

a. Only key milestones that are important for the fleet command, customers and other external agencies (e.g. docking, undocking and sea trials) should be precisely scheduled at planning time, not the individual tasks.

b. In addition to management reserves in the budget, we should also provision time and resource buffers that can be used by workflows that need them the most.

c. Monitoring time buffers is a quick and easy way of dynamically identifying the criticality of workflows. Workflows that are consuming their time buffers at the fastest rate get the highest priority when allocating and assigning resources; and budgetary reserves and resource buffers need to be spent only on those workflows that have consumed their time buffers to the extent that they are beginning to create risk for external commitments.



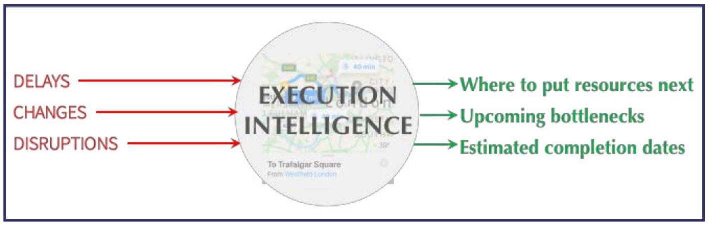
In summary, a combination of 2-Tiered Workflows and Dynamic Buffer Management can solve longstanding scheduling problems:

- Tier-1 workflows, due-dates for key milestones and overall resource requirements, along with budget reserves and resource and time buffers, are established at the time of planning. Tier-2 workflows, task schedules and resource assignments are left flexible for execution.
- Monitoring time buffers in execution provides dynamic priorities for resources as well as forward-looking alerts for management intervention.
- Faster speed and higher efficiencies are achieved by adopting a "focus and finish" approach for Tier-1 tasks, and by working according to dynamic priorities and solving problems based on forward-looking alerts.

Project durations and labor costs in the industry have been reduced by at least 20% with the solution outlined above. There's a caveat though: scheduling is not a mathematical exercise that takes place on the planners' desks; the resulting schedules must be actualized on the frontline to impact time and cost performance.

Adding execution logic to a project management system is akin to moving from static maps to GPS systems for driving. As delays, changes and disruptions happen, the system can automatically direct resources to the most optimal tasks, and provides reliable estimates of completion dates and forward looking alerts to management. It gets project teams to their "destination" faster and more efficiently.

[3] Scheduling logic invented by Dr. E. M. Goldratt (Critical Chain, 1997).



Organizational Implications of Change in Scheduling

Schedules cannot be actualized without organizational processes and measurements to support them. For example, processes and measurements related to daily task management, crew composition, weekly resource management, materials kitting, and problem identification and resolution, all need to be aligned with the planning and execution logic, and the resulting speed that comes with it.

Another important aspect is sustainment. Availability projects are unique in that frontline managers need to have a certain amount of flexibility; at the same time, that flexibility should not be misused. Therefore, an operating motto is required that provides a practical approach for making good choices. Experience from NAVAIR and others, "Focus & Finish" (focus on what you are working on, and finish it before starting the next block of work) is a suitable operating motto for projects.

Additionally, managers at all levels — from shipyard leaders to frontline supervisors need to be trained in both the value and principles of scheduling non-deterministic operations. (While they are generally great at soft aspects of management, the value and principles of scheduling are not well appreciated or understood by them.)

While organizational inertia is always a factor, the good news is that the change itself is quite straightforward and execution rates improve as soon as the schedules are put into practice. Moreover, NAVSEA already has a burning platform of "fleet availability and readiness" that can galvanize shipyards into action, and knock down any barriers that stand in the way.