Manufacturing Assembly Plan (MAP) Tool: Bridging the Gap between Performance and the Construction Process

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Abstract

The VIRGINIA Class Submarine (VCS) is a class of nuclear-powered fast attack submarines in service with the United States Navy. For over a decade, General Dynamics Electric Boat and Huntington Ingalls Industries' Newport News Shipbuilding have teamed to design and construct the VCS. Under this unique class build plan arrangement, major modules are assigned to respective yards and the delivery of each submarine is alternated between the shipbuilders. The Government and both shipbuilders continue to find ways to reduce cost, improve schedule, and increase capabilities on the program.

One way of achieving these objectives is to optimize the construction build strategy. To understand how this is accomplished, one must first understand the manufacturing assembly plan (MAP) for the VCS program. VCS has 10 major hull sections, all of which are outfitted with systems and components. Over time, the shipbuilders have refined their techniques and processes to come up with the four-module build plan. This includes assembling deck packages and hull sections into four larger structures; (a) Section 1/2A, (b) Section 2B-5, (c) Section 6-7, (d) Section 8/9.

This presentation further explains the four module build plan and provides an in-depth look into touch labor hours by (a) Section 1/2A, (b) Section 2B/5, (c) Section 6/7, (d) Section 8/9, (e) Final Assembly and Test (FAT), and (f) Post Shakedown Availability (PSA). Further understanding these concepts will not only allow cost estimators to better understand the current construction build strategy on VCS, but it will also enable cost estimates to be reflective of how the shipbuilders assemble VCS. Further analysis may lead to other potential cost reduction initiatives and also lead to estimating methodologies for other submarine programs/ enhancements.

Current Environment

- Problem Statement:

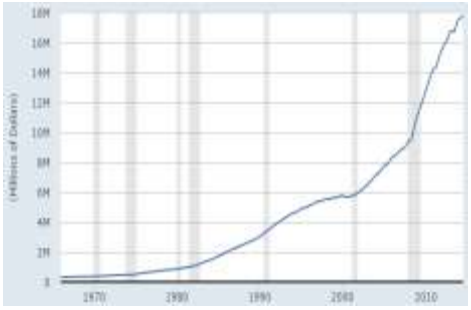


Figure 1: Federal Debt: Total Public Debt (2014)

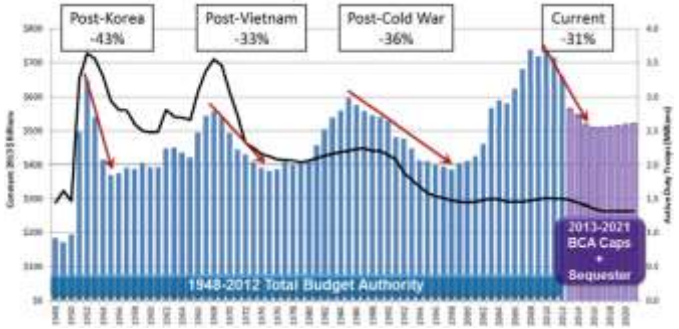


Figure 2: U.S. Defense Budget (Plumer, 2013)

Figure 3: The Challenge of 2020 (Padilla, 2014)

A growing national debt…

…is applying economic and political pressure on all Government spending, in general, and on the Department of Defense budget, in particular…

…all while the threat environment is growing in quantity, variety, and complexity.

In short, the <u>demand</u> signal for capabilities is <u>higher</u> while <u>resources are shrinking</u>

- Outcome: We are all tasked to do more with less
  - Better Purchasing Power (BPP) 3.0 – the latest step in DoD's continuing effort to improve its acquisition process, is a natural development from this call to action

VIRGINIA Class Submarines

What is VIRGINIA Class?

- Attack nuclear-powered submarine
- Unique industrial arrangement in which the sub is built by two shipyards;
  - Electric Boat (EB)
  - Newport News Shipyard (NNS)
- Four Blocks under contract, 28 total subs
  - Block I: Commissioned
  - Block II: Commissioned
  - Block III: Under contract and in construction, first ship commissioned
  - Block IV: Under contract, first two ships under construction

How does the VIRGINIA Class program address the current environment?

- Continues to promote a culture of affordability to address shrinking budget
  - DFA (Design for Affordability) & RTOC (Reduction of Total Ownership Costs) Initiatives
- Continues to promote added capability to address future threats
  - Added strike capability through Virginia Payload Module (VPM)

"The VIRGINIA Class program is a model of acquisition excellence." - Rear Adm. David Johnson

VIRGINIA Class Submarines

- VIRGINIA Class Program Office established a three element strategy to meet CNO's Cost Reduction Goal in 2012 (Johnson, Drakeley, & Smith, 2008)

- Design for Cost Reduction
- Procurement Rate
- Construction Performance

- Strong understanding of the manufacturing assembly plan (MAP) is necessary to achieve the three element strategy
- Efficiencies were gained from optimizing the build plan and the construction schedule

Overview

- Objective: To provide a tool that offers an additional perspective in understanding a program holistically and that is aligned with how the product is manufactured.

- Method: The tool will reflect the Manufacturing Assembly Plan (MAP), which for VIRGINIA Class is known as the Four-Module Build Plan.

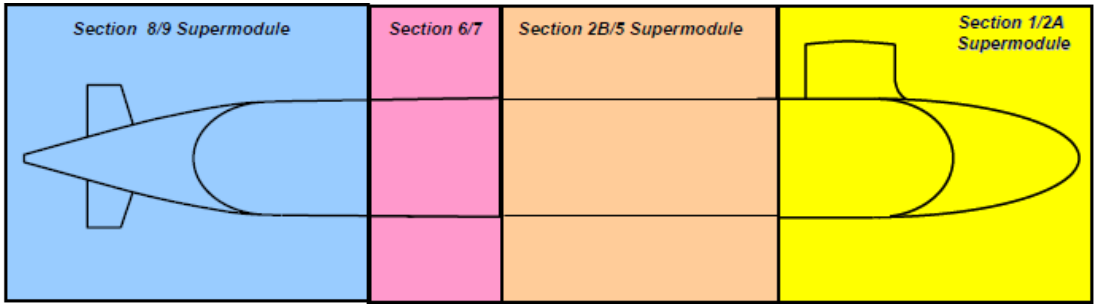


Figure 4: Four-Module Build Plan (Johnson, Drakeley, and Smith, 2010).

- Consequence: MAP tool exists at the intersection of Program Management, Earned Value Management, and Cost Estimating.

This presentation has been sanitized and is intended for conceptual purposes only.

Manufacturing Assembly Plan (MAP)

- The MAP is categorized in 6 sections.
  - Section 1/2A
  - Section 2B/5
  - Section 6/7
  - Section 8/9
  - FAT (Final Assembly Test)
  - PSA (Post Shakedown Availability)
- Current approach focuses on End Use (Touch Labor) hours.
- Shown below is a diagram of the modules on the USS New Mexico (SSN779).

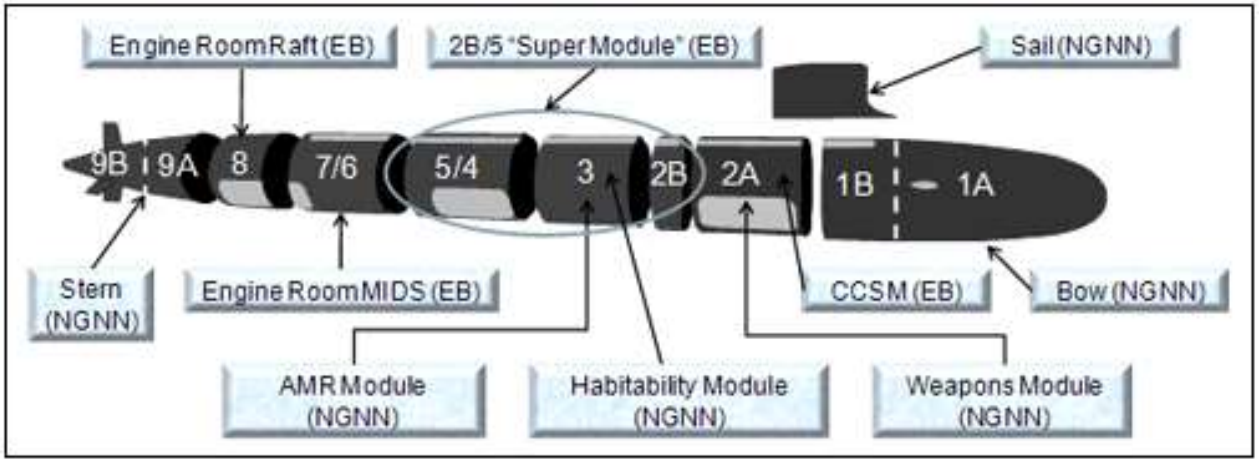
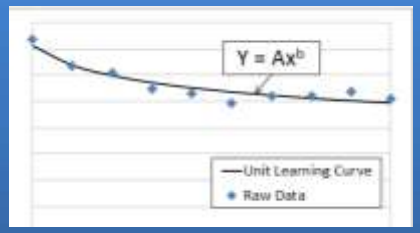


Figure 5: Sections and Modules of a VIRGINIA Class Submarine (2015)
Note: Graphic dated prior to Northrop Grumman's spin-off of its shipbuilding division

MAP Applications

Competencies

Cost Estimating

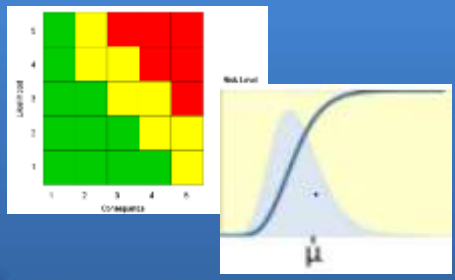


Hours as a function of units

Earned Value Management

Performance as a function of time

Program Management

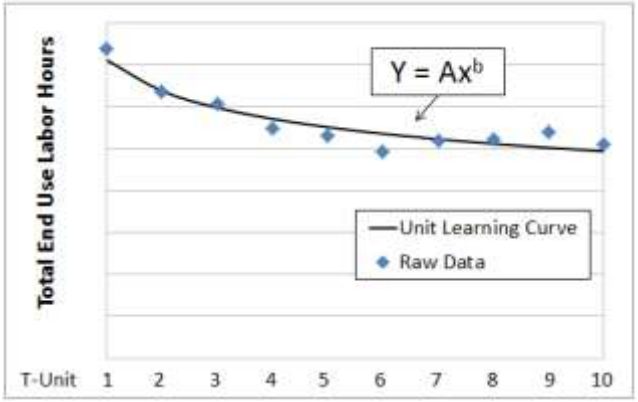


Assessing risk and making strategic decisions

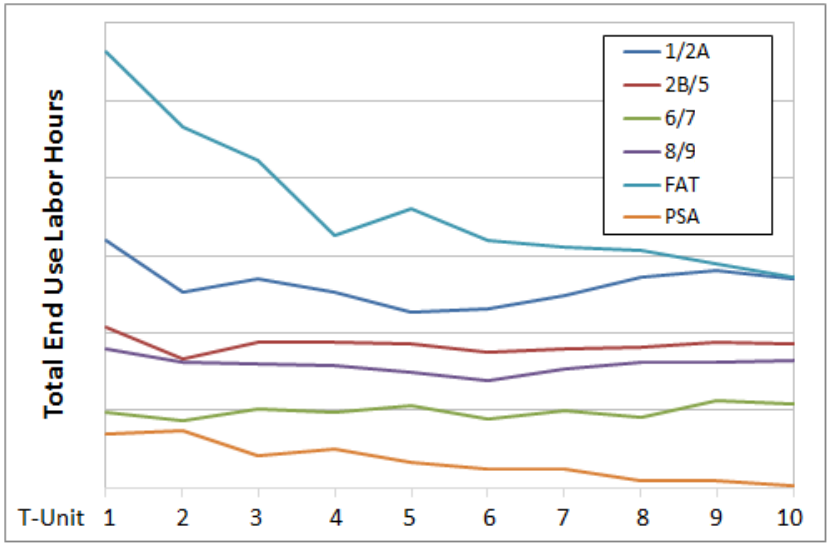
Applications cross several competencies, ultimately expanding the toolbox available to decision makers

Cost Estimating Analysis

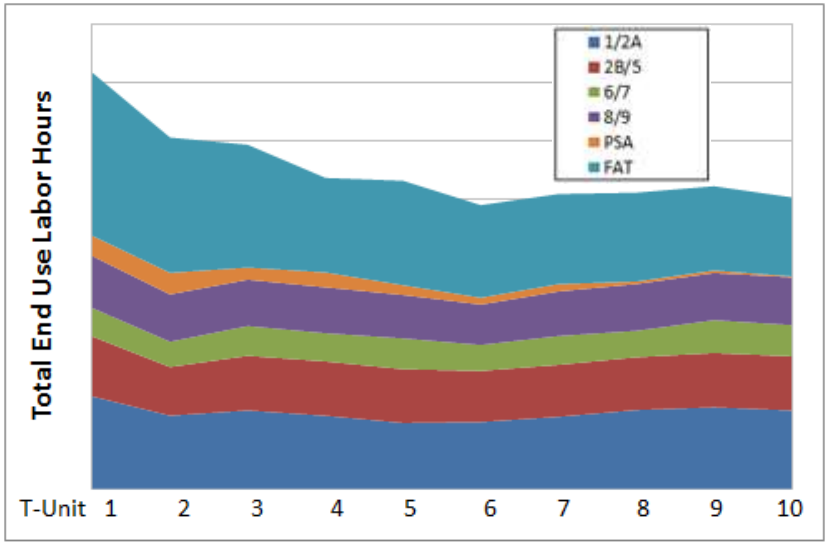
- Learning Curve analysis has been typically applied to total End Use Hours.



- End Use Hours were further analyzed by the 6 sections of MAP.



Scatter Plot

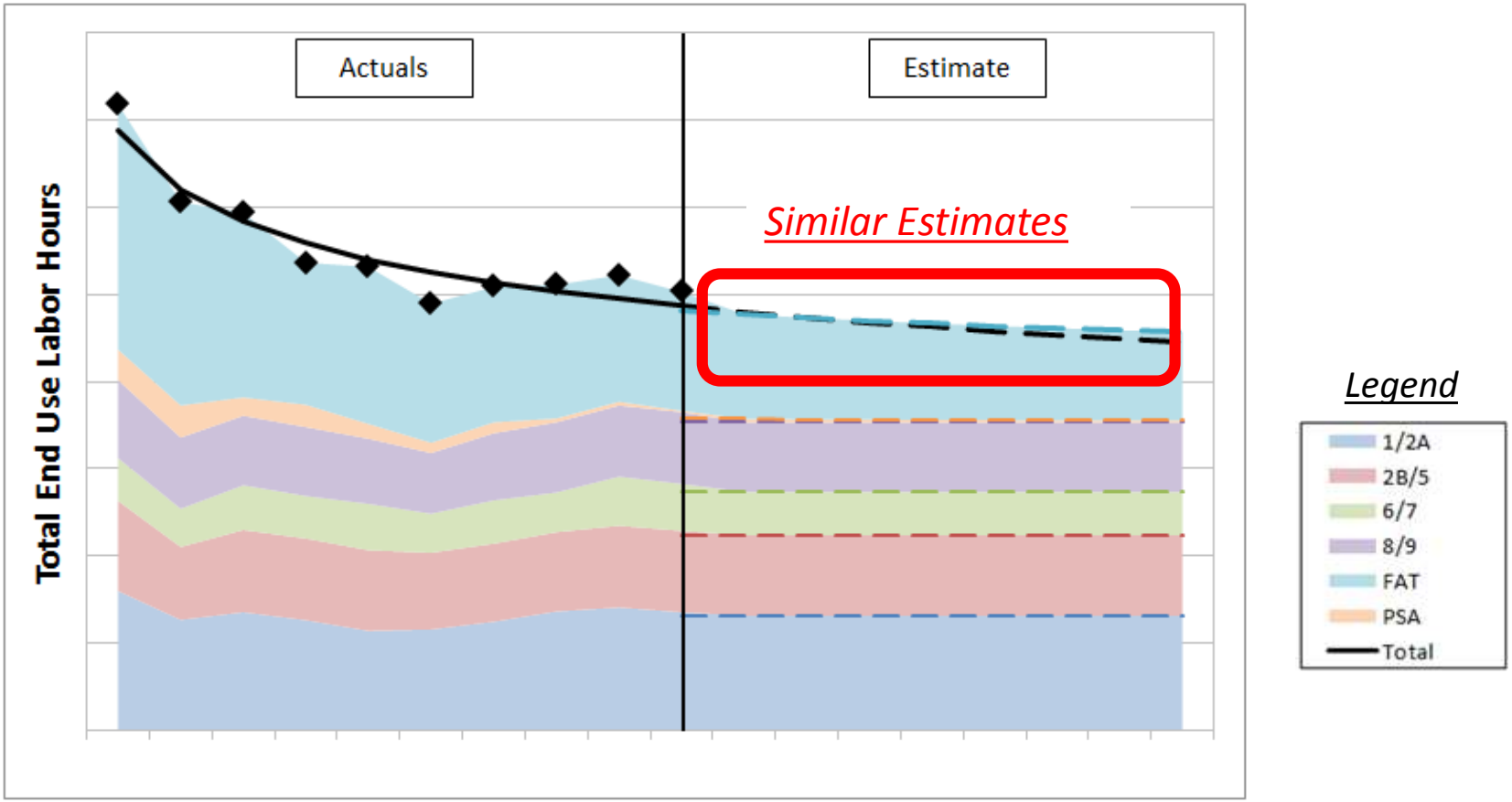


Area Chart

MAP identifies drivers of “learning” impacts.

Cost Estimating Comparisons

- Estimating at the total level vs. estimating at lower levels provide similar estimates.



Estimating at lower levels provide insight into MAP and facilitates communication between cost estimators, program managers, and shipbuilders.

Forecasting/EVM Methodologies

- Two different approaches to forecasting costs during execution

Regression techniques

- Used Weibull regression to analyze End Use labor hours for sections of the MAP
  - Leveraged research from following studies:
    - 'Ship Construction Estimates at Completion: A New Technique Using the Weibull Function' by Shawn Rudolph
    - 'Forecasting Research & Development Program Budgets Using The Weibull Model' by Thomas W. Brown, Captain

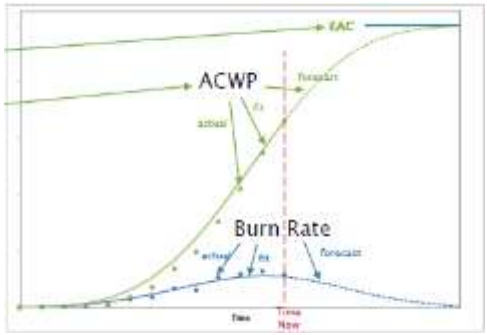
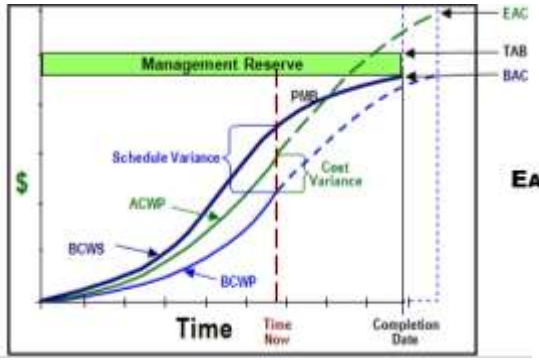


Figure 6: Ship Construction Estimates at Completion: A New Technique Using the Weibull Function (Rudolph, 2010)

Performance Assessments

- Analyze each section independently for the most probable performance factor for the BCWR (Budgeted Cost Work Remaining):
  - Historical final performance factors
  - % Comp To-Go analysis in relation to prior hulls
  - CPI/SPI Trend data: 3/6/9/12 Months
  - EVM Techniques: (Math Extension, 50/50, 80/20, CPI*SPI…)
  - Performance blends incorporating Cumulative Cost/Schedule performance, current trends, % Complete To-Go analysis and others



EVM Regression Analysis

- Analyzed burn rate (i.e., Current Period ACWP) as a function of % Duration
- Following steps were taken to analyze each section of the MAP

1 → 2 → 3

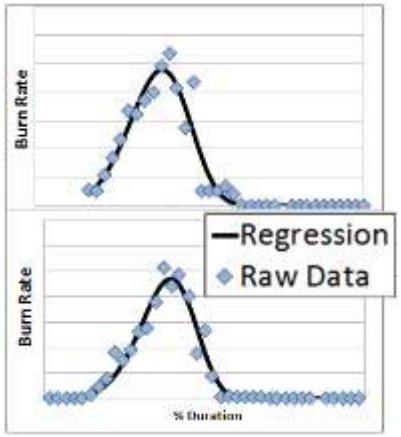
Perform Weibull regression for each unit & section.

Record Weibull parameters for each unit & section.

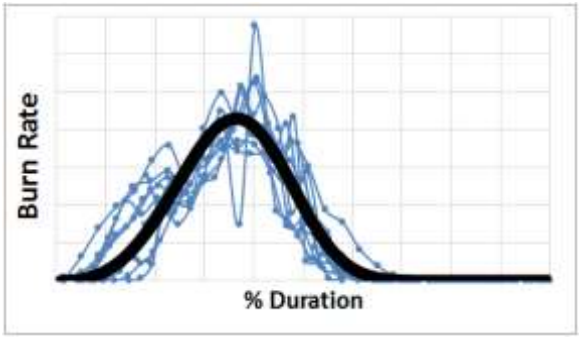
Avg Weibull parameters to develop estimated avg burn rate.

Unit 1

Unit 2



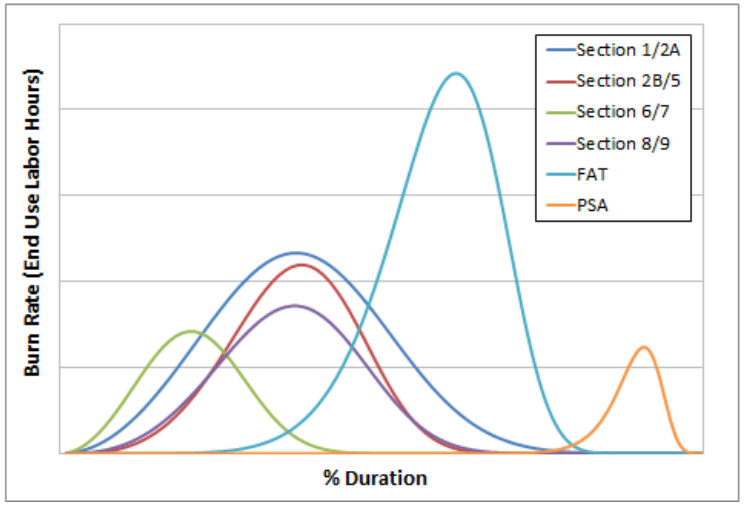
Section X			
	Weibull Parameters		
Unit	Shape	Scale	Constant
1	#	#	#
2	#	#	#
3	#	#	#
4	#	#	#
5	#	#	#
6	#	#	#
7	#	#	#
8	#	#	#
9	#	#	#
10	#	#	#
Avg	#	#	#
StDev	#	#	#
CV	#	#	#



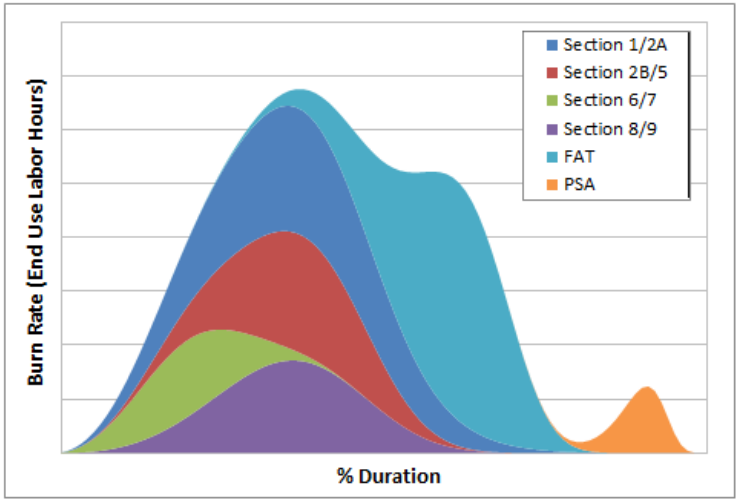
Raw Data
Estimated Avg Burn Rate

Earned Value Management (EVM)

- Performance drivers can be isolated to the section of the hull where the work is being performed
  - By understanding how each section is linked to each other, one can potentially diagnose a schedule slip early and alert the Program Manager to a likely overall program delay.
    - Delays in Section 6/7 would cause a delay to FAT but not to Section 8/9
  - Cost performance can be isolated to MAP sections rather than overall trade or functional categories.
    - For example, Electrical work in Section 1/2A may be more difficult and complex than in Section 8/9 with a lower cost performance. This would allow the analyst to apply a different performance factor ensuring the most realistic forecasting methodologies are used in the EAC (Estimate at Completion).
- Performing EVM regression analysis enables development of workload profiles.



Scatter Plot

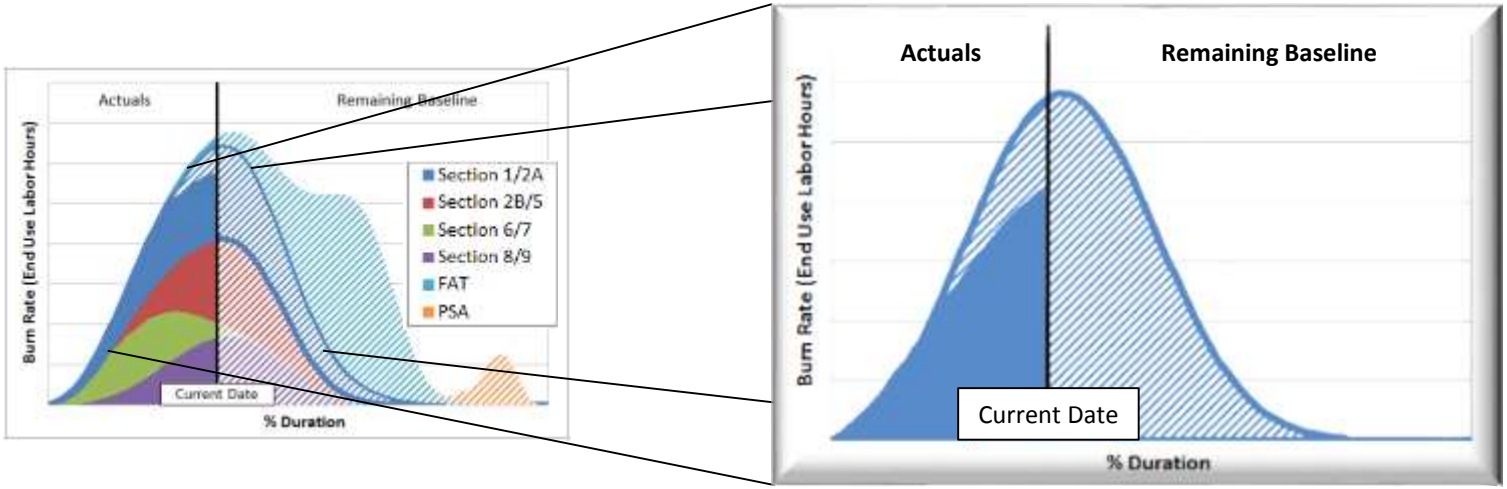


Area Chart

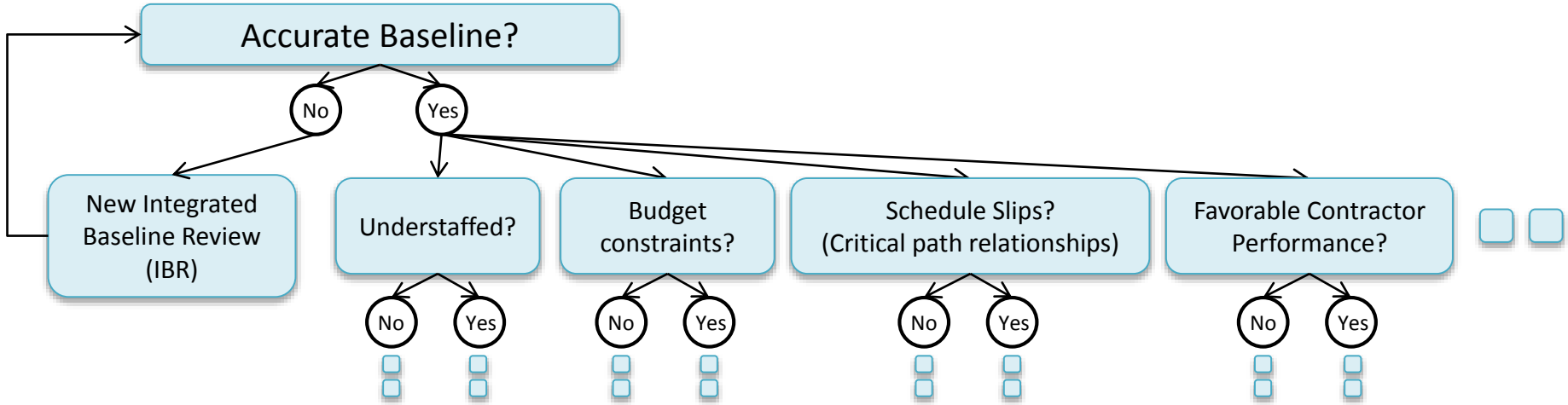
Understanding how the product is manufactured (i.e., MAP) enables better forecasting of the cost and schedule relationships that exist between sections.

Program Management

- Case Study: Burn rate to date is lower than the original baseline



- Program Office faces a series of decision trees

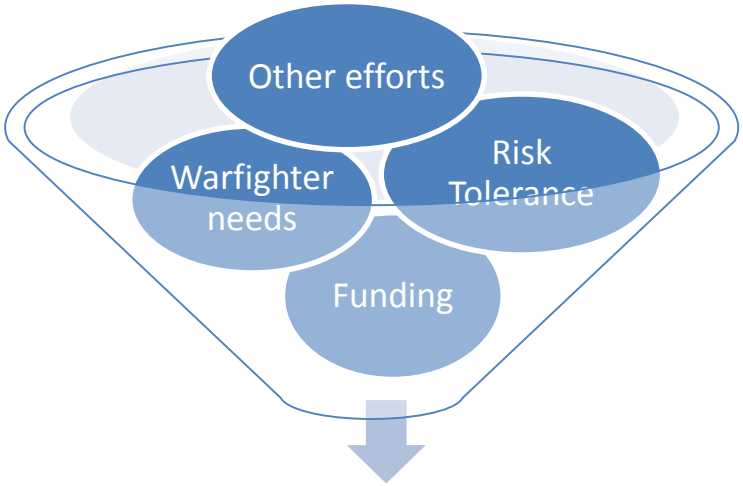


MAP supports program assessment and root-cause analysis

Program Management (cont.)

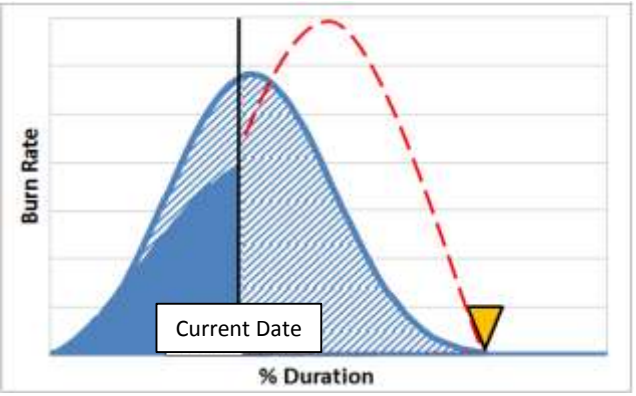
- Results from root cause analysis constrain decisions

The Program's choices exist along a continuum between increasing resources and relaxing schedule/requirements given several constraints:

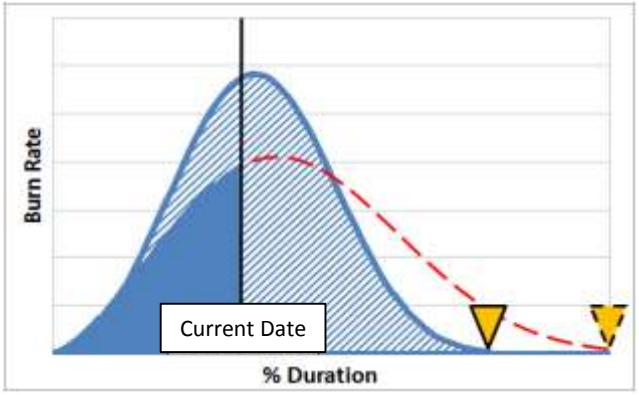


Strategic Decisions

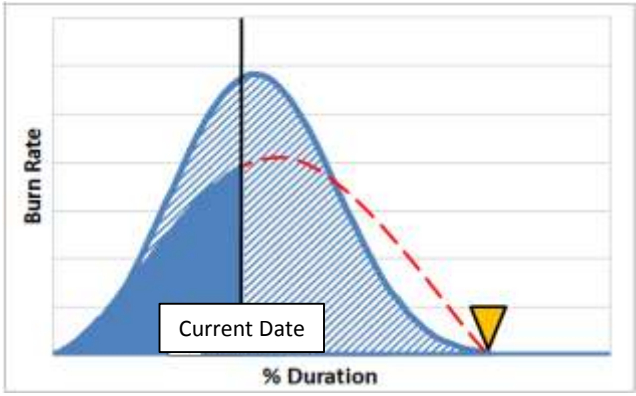
Increase resources to meet schedule event



Maintain original resource plan by delaying schedule event



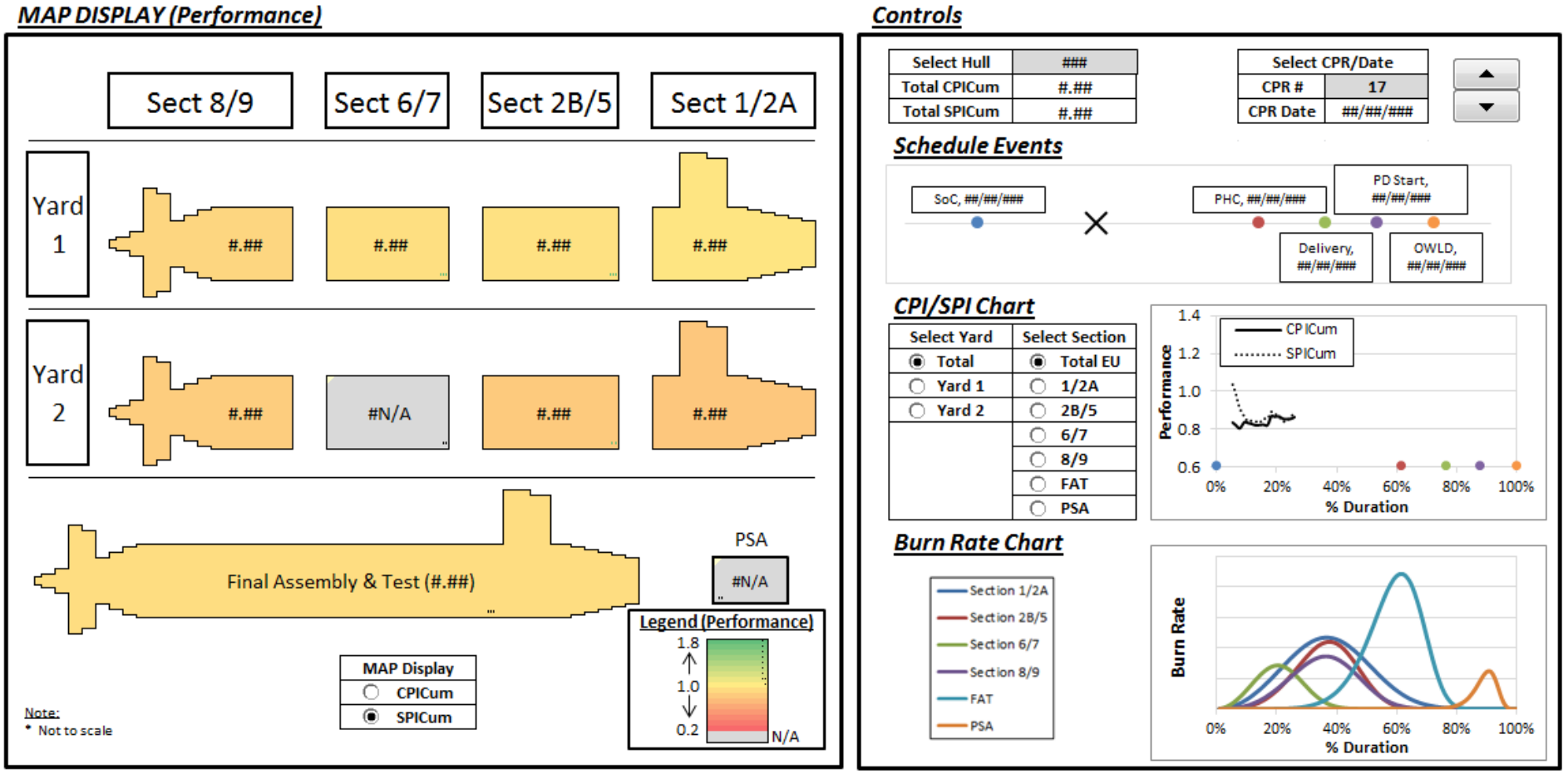
Favorable performance indicating a surplus of resources



MAP enables informative and strategic decision making

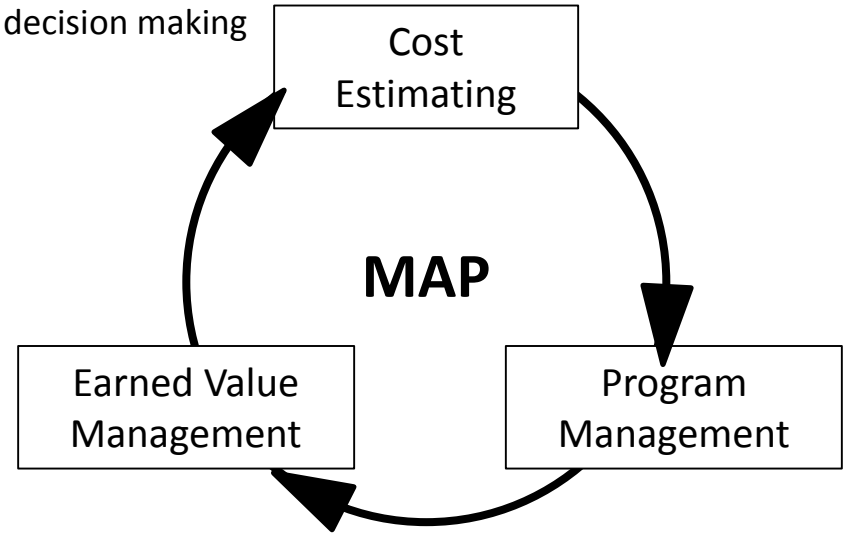
MAP tool demo

- Screenshot of MAP tool (sanitized for the purpose of the presentation)



Conclusions

- Manufacturing Assembly Plan (MAP) offers an additional perspective in understanding a program by aligning cost estimating, earned value management, and program management to how the product is manufactured
- Cost Estimating
  - Estimating at lower levels provide insight into MAP and facilitates communication between cost estimators, program managers, and shipbuilders
- Earned Value Management
  - Sectional linking allows for early detection of potential schedule driver delays
  - Isolates cost performance drivers to individual sections rather than broad areas of the hull
- Program Management
  - Supports root cause analysis
  - Enables strategic decision making



Future Work

- Critical Path:
  - Analyze interdependencies across MAP sections
- Early Indicators:
  - Examine relationships between MAP sections and historical performance indices (i.e. CPI and SPI)
- Refining EACs and Cost Estimates:
  - Further understand the impacts of 2/year build rate
  - Crosscheck against current EACs and cost estimating methodologies
- Risk:
  - Study the variation in the historical data to establish risk bounds
- Facilitate Decision Making:
  - Incorporate aforementioned results into the MAP tool, providing a graphical representation of the analysis

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