Proceedings of the 2020 Winter Simulation Conference
P. Brown, C. Kawazoe, A. Nguyen

MODELING AND SIMULATION: BALANCING PERFORMANCE, SCHEDULE, AND COST

Paul Brown

Systecon North America
1911 N Fort Myer Dr, Suite 300
Arlington, VA 22209, USA

Courtney Kawazoe
Alex Nguyen

Naval Surface Warfare Center
Port Hueneme Division
4363 Missile Way
Port Hueneme, CA, 93043, USA

ABSTRACT

Given the rapid technological advances realized in the defense industry, asymmetric threats present new challenges to the US Navy. Directed Energy (DE), a rapid prototyping, experimentation, and demonstration (RPED) initiative seeks to develop and deliver advanced laser capabilities to the fleet to mitigate the newly discovered capability gaps. DE programs will utilize a wholeness approach to minimize excess spending, keep a tight schedule, and meet high readiness requirements all at best value with analysis conducted in the early stages of its life. Monitoring readiness of the DE programs includes tracking metrics such as operational availability and mission effectiveness. Evaluating DE design performance during preliminary design reviews, as well as throughout the acquisition milestones, allows NAVSEA the opportunity to make informed trade decisions in the design and production phases. Capturing design trades early in the system lifecycle will both increase Operational Availability as well as decrease Total Ownership Cost.

1 INTRODUCTION

The U.S. Navy is venturing into a time of significant and tumultuous change. We are faced with threats on multiple fronts. Although threats on multiple fronts are nothing new; more alarming are those threats' positions of national power and their increasing creativity in inflicting damage to our assets. The U.S. Navy no longer holds a position of maritime superiority to the extent that we had in the past. As the operating environment continues to shift at an accelerated rate, the U.S. Navy will have to rapidly evolve to capably engage the emerging threats.

The U.S. Navy is working at a rapid pace to develop, deliver and mature laser capabilities to place these systems into the hands of the warfighter. One of the emerging threats that the U.S. Navy is facing is the introduction of unmanned aerial vehicles (UAVs) into the battlespace. UAVs are lightweight, maneuverable, and easily weaponized allowing the enemy access to a low-cost, highly effective damage threat to our surface Navy. The current capabilities aboard our surface fleet vessels allow only for UAVs to be neutralized utilizing standard ballistic methods. However, this strategy is neither cost nor performance effective. The introduction of Directed Energy capabilities allows the U.S. Navy to combat UAV threats at pennies on the dollar, increasing performance and cost effectiveness while reutilizing much of the ship's existing infrastructure. Additionally, the advanced optics used in Directed Energy technologies enables the U.S. Navy to enhance a ship's situational awareness by increasing the range of its vision. This is invaluable in an environment where radar operations may need to be reduced to a minimum in order to prevent unwanted enemy detection and engagement.

With this imminent UAV threat, Directed Energy became a Rapid Prototyping Experimentation and Demonstration (RPED) Program. Directed Energy would become an extremely accelerated acquisition program, delivering our surface fleet the capability to combat the UAV threat and expand its arsenal. However, with this accelerated acquisition comes a complex challenge: how to balance the Department of Defense (DoD) cost as an independent variable trade spaces of schedule, cost, and performance while

978-1-7281-9499-8/20/$31.00 ©2020 IEEE

maintaining schedule as the top priority. Directed Energy is currently using an advanced suite of tools in order to assist with the intricate design decisions that are made during the acquisition process.

As the U.S. Navy begins to field these RPED programs it minimizes the time allowed to plan for the operation and sustainment (O&S) of the system. It is estimated that 60-80% of a program's total budget is spent in the O&S phase of the system's lifecycle. Recognizing the importance for the Directed Energy capabilities to be ready and affordable, the government is utilizing a tool to conduct Reliability, Availability, Maintainability and Cost (RAM-C) analysis. While schedule is the top priority for Directed Energy, the U.S. Navy is working to control O&S costs by modeling the system to predict and build out the sustainment strategy. This readiness model will predict the system demand for spares, resources, and maintenance and output an optimized system product support strategy.

The lack of upfront sustainment planning results in DoD programs to incur cost overruns in addition to systems being unable to meet its requirements. In order to see how our spares budget can be best utilized, we need to have a measure of effectiveness to balance our investment against for a proper optimization.

When looking to properly model sustainment of a complex system, like Directed Energy, a budget must be optimized against another measure of effectiveness. For this model, we have decided to optimize the Operational Availability (Ao) of our system as impacted by spares. This means that we will be measuring the different fleet or system availabilities based on different investments in spares packages. Since an item-by-item or even system-by-system model is usually erroneous and redundant, it would most likely result in a suboptimal spares solution. When spares are pooled at more centralized locations based on demands over the entire fleet, we have found we are able to save the U.S. Navy money and space in on board spare parts, as shown with the Air Missile Defense Radar (AMDR) Program. In that case, the AMDR needed to be available, or not under any kind of repairs, 99.98% of the time they were deployed on a ship. In our case, our requirements are on the budget for these systems, so we will find the highest Ao we obtainable if we properly spend our budget. To build this readiness model, The U.S. Navy will be using a tool suite called the Opus Suite.

.

2 BACKGROUND ON THE OPUS SUITE

The Opus Suite, a RAM-C tool suite, optimizes supply system performance by balancing O&S cost against system availability (finding the "Knee in the Curve"). Determining the optimal level of spares has been one of the most common uses of the Opus Suite since the 1970s. Developed in Stockholm, Sweden, the software is now used to optimize spares in numerous countries for a wide span of projects that cross the commercial and defense sectors. Opus Suite is comprised of three modules: OPUS10, SIMLOX, and CATLOC. OPUS10 is used for spare parts optimization and logistics support analysis. SIMLOX supports event driven simulation utilizing more dynamic and realistic scenario inputs to model a system's operational effectiveness. CATLOC is used to model development, acquisition, O&S cost over time

.

3 MODELING METHODS

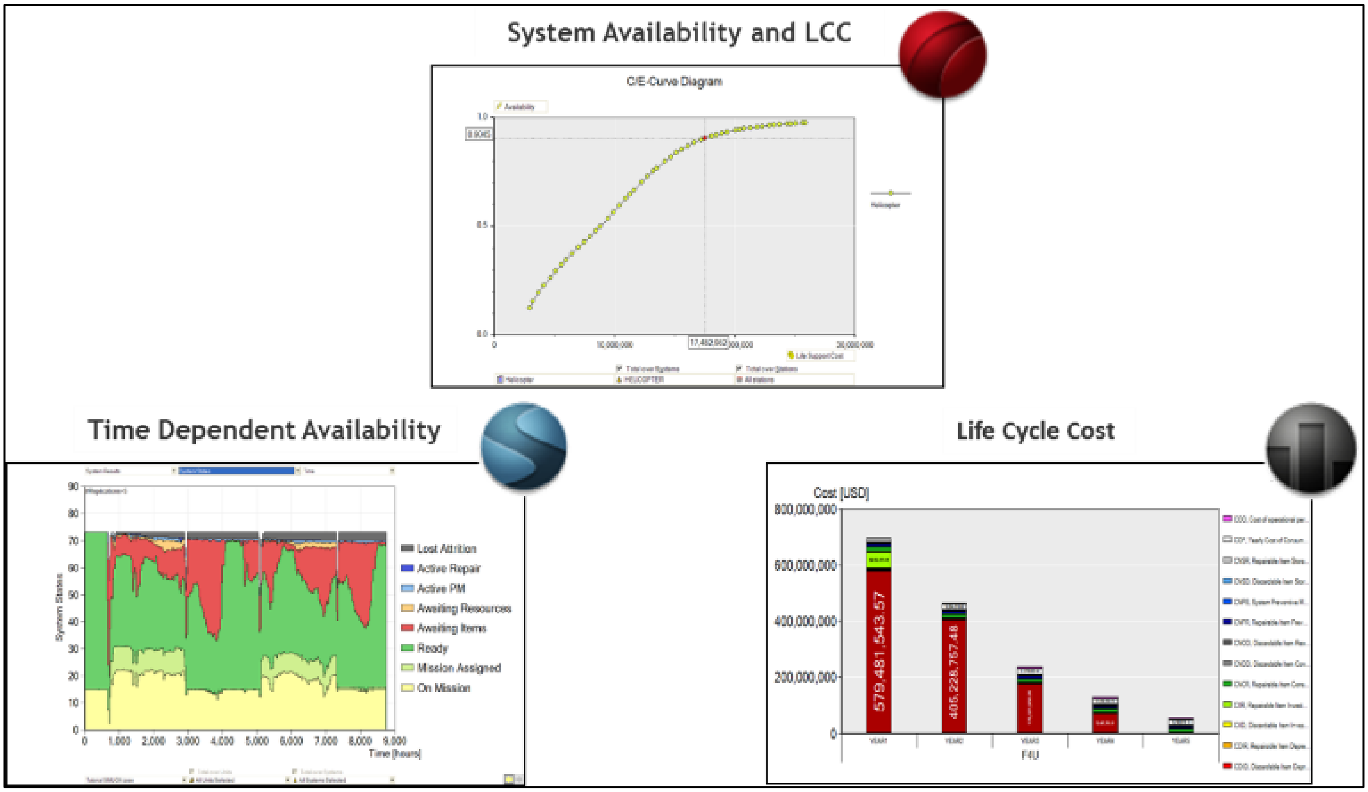

Figure 1: Examples of Results from the tools in the Opus Suite, from right to left; SIMLOX, OPUS10, and CATLOC.

Developing a Product Support model using the Opus Suite involves three related input data: Technical System Design, Support System Design, and Optional Concept (figure 2). These input data categories are used to create an integrated model that represents not only the system being supported, but also the support system itself. Data is modeled to the level of detail required to provide decisions makers the accuracy needed to support real-time decision making.

3.1 Technical System Design

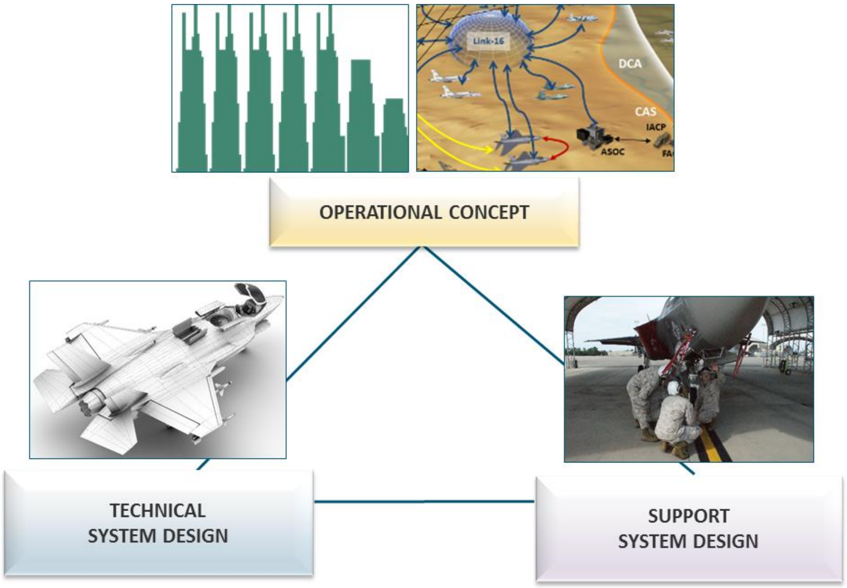

Figure 2: The three areas of data needed to create a model.

The first major data element associated with a physical system design is item data, often referred to as a Bill of Material (BOM). Crucial metadata related to individual BOM elements, or parts, are reliability (failure rate) and cost (unit price). An indentured BOM (top-down break-down) further describes the hierarchical structure of a system as it relates to sub-systems, assemblies, Line Replaceable Units (LRUs), and Secondary Replaceable Units (SRUs). Depending on the LRUs position in the indenture structure, metadata related to removal and replacement from the next higher assembly, as well as the repair of the failed item are documented as Mean Time to Repair (MTTR). These factors are modeled along with the associated unit level manpower, maintenance equipment, and costs associated with accomplishing the task to show the full impact of a given failure. These are the minimal data required to perform steady-state (analytical) optimization on a repairable system, agnostic of the support system or utilization profile.

In order to preform "readiness based" optimizations two more major categories of data are required, detailed operational concept (discussed later) and the systems redundancy characteristics as it relates to mission critical failures/system mean time between critical failure. A system/mission critical failure can be described by Reliability Block Diagrams (RBDs), or Failure Modes (FM), Effects, and Criticality Analysis (FMECA) or a combination of both. Systems designed with built in redundancy/graceful degradation may continue to perform their function without immediate repair. Similarly, particular LRU or SRU FMs may have "next higher" effects that in isolation do not effective the top-level system or sub-system's ability to perform its function. In this way the FMECA, and sometimes fault tree analysis, are used to describe aggregated failures' top-level effects and form the basis for number required of number in system (M of N) redundancy. In simple parallel redundancy cases M of N requirements can be modeled in independent series. However, some complex systems exhibit a "fan out" of failure effects as multiple LRUs work in conjunction to perform a particular system function. The result of complex system fan out can drive extreme mission criticality dependencies on particular "controller" LRUs, making their effect on readiness more significant then modeled in the analytical case.

Long run analytical optimizations are excellent at meeting average system effectiveness across an enterprise of systems; eventually all failures that occurred (both critical and non-critical) will generate supply system demands and need to be replaced within the system. However, in order to meet strict, independent missions, a readiness based stochastic approach is needed to ensure the desired level of mission effectiveness is achieved on an individual system basis.

.

3.2 Support System Design

The next type of data needed to build a support model is location data, such as operational sites, storage facilities, and any repair infrastructure that will or already exist. Additionally, the transportation policy between sites and how they will support one another are vital to determining how the support organization and possible repair strategies will dictate the calculation of Mean Logistics Delay Time. When modeling complex systems, model only locations which impact the system(s) being modeled. Grouping locations with common capabilities into one node/model structure is a good way to simplify complex models. For example, if modeling the sparing needs of different operational sites and intermediate level supporting depots, it may be unnecessary to model individual part manufacturers if the purpose of the model is to develop operational and intermediate results. Since the model does not need to account for manufacturer spares one location can be used to model all of the manufacturers with different logistics times for each of the individual parts.

Understanding the repair capabilities at each support location, for example MTTR, is important to defining item and location repair policies within the model. Depending on the data available or the purpose of the model, other site capabilities, like storage of spares and/or resources, or ability to deploy systems, are also important to consider when uniting the technical system design and operational concepts together.

3.3 Operational Concept

The operational concept, or Concept of Operations (CONOPs), describes the systems' mission(s) objectives. Each mission can be decomposed into an operational profile, or Design Reference Mission Profile (DRMP), which defines the mode(s) in which system will operate and in what duration(s) and system/sub-system utilization(s) will be needed to achieve mission objectives. In the long run analytical case operational concept can be simply described as the product of system utilization and the optimization length. However, complex missions aggregated into operational profiles, may leverage a variety of common and unique RBD systems architectures (to include different M of N requirements) depending on the system operational modes defined by the mission criteria, as well as varying sub-mission durations. Moreover, the criticality of a failure is dictated by the failures effect on the mission being performed in the operational profile. Therefore, dynamic operational concepts (modeled stochastically) are also a key contributor to a readiness based sparing optimization.

Once the technical system design, support structure, and operational profile are defined and inputted into the tool the output of the model is a Cost/Effectiveness (C/E) curve where we are able to analyze various Measures of Effectiveness (MoE) such as availability, mean down time, mean waiting time, probability of no backorders etc., against life cycle cost. Each point on the C/E curve represents an optimized product support strategy, including an optimal spares quantity, repair resources, and maintenance locations. The program can then choose a point based off their program's budgetary constraints. A fully built out Directed Energy OPUS model allows decision makers to make data driven decisions with a full understanding of the impacts of their decisions.

3.4 Summary

These three related input data are used in product support optimizations such as multi-echelon Readiness Based Sparing (RBS), Location of Repair Analysis (LORA), and manpower planning. The product support model leverages the discussed input parameters to calculate metrics which are balanced against cost and resource constraints to achieve an optimized system effectiveness/readiness level (Figure 3).

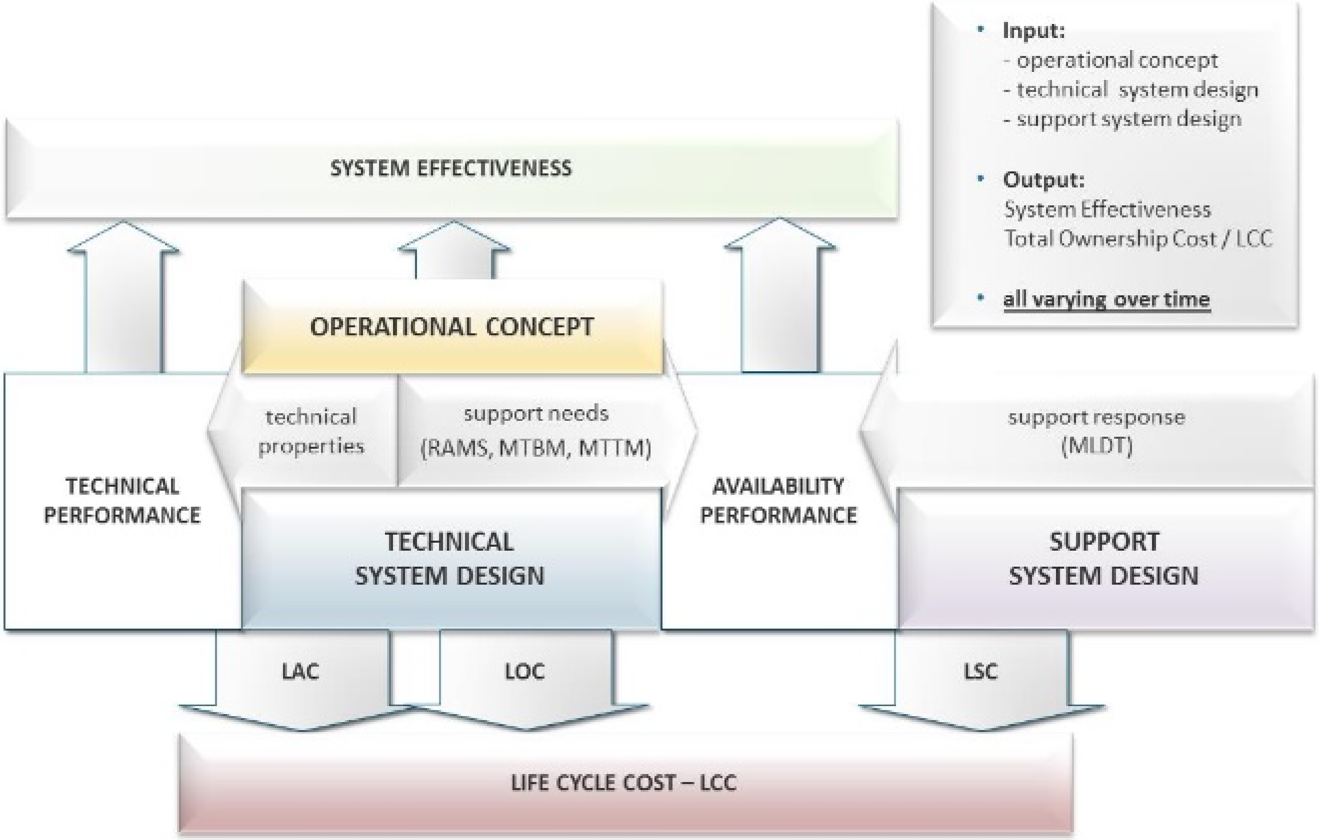

Figure 3: Summary of inputs and outputs of a model.

4 SUCCESS CASE: AMDR

One program that has greatly benefitted from the use of the Opus Suite, is the AMDR Program. The AMDR Program is currently utilizing the OPUS10 and SIMLOX modules to perform RBS, conduct decision support and trade study analyses. The modules are also being used to provide O&S cost estimate input data used in budget planning and appropriation of Ship Construction Navy and Operation and Maintenance Navy funds. Complex redundancies and unique operational profiles associated with AMDR's system design, DRMP, and CONOPS drives a divergence between the analytically predicted steady state availability in the OPUS10 optimization, and the stochastically modeled mission specific availability in SIMLOX. For example, when modeling operational hours in OPUS10, we model that there will be 24 hours of operation, and this will help us get our optimal spares allocation. When we then model the same 24 hours of operation in SIMLOX, there are two very different ways to model this; twenty-four 1-hour missions, or one 24-hour mission. Both operations having an average mission time of 10% but have drastically different support requirements.

Opus Suite was used to gain insight into the contractor solution and show if various proposals would meet cost and performance key performance indicators and the impact of various MoE. It also enabled the AMDR leadership to force system design changes and modify provisioning to meet both inherent Availability and Ao requirements. This has resulted in cost savings of $120M and unknown cost avoidance from simply doing it right the first time to avoid “surprises” (avoidable outcomes that are the result of not modeling and simulating early in a program’s lifecycle).

AMDR plans to use Opus Suite throughout the life cycle and has included CLINs in contract requiring Original Equipment Manufacturer to use OPUS Suite and deliver OPUS models to the government. Opus Suite is used across integrated product teams, including for production of their annual life cycle cost estimate. The government is now able to organically monitor and influence performance and cost.

5 CONCLUSIONS

In the current hostile geopolitical and constrained budgetary climate, arming the warfighter with capable, sustainable, and affordable systems is crucial. Ultimately the goal end state is that robust product support modeling and Simulation is standard across the U.S. Navy acquisition community, but we understand that establishing the analytics capabilities necessary to perform the Modeling and Simulation (M&S) takes time. For now, AMDR and Directed Energy programs that utilize these proven Product Support M&S tools are not only framing the success of their programs but are also paving a way forward and establishing best practices for future acquisition programs within the U.S. Navy.

AUTHOR BIOGRAPHIES

Paul Brown is a senior analyst with Systecon North America. In his current role, Paul provides life cycle logistics and sustainment support within the DoD, analyzing the trade-offs between system costs and readiness. His prior experience in the defense industry has included a wide-range of cost estimating and analysis and workforce analysis supporting various members of the Intelligence Community, as well as the Army, Navy, Marine Corps, and select civilian agencies. His email address is paul.brown@systecon.us.

Courtnet Kawazoe is an Operations Research Analyst at the Naval Surface Warfare Center, Port Hueneme Division (NSWC PHD). She earned her Bachelor’s Degree in Economics at the University of California, San Diego. She is currently supporting Directed Energy Product Support Modeling and Simulation efforts to at NSWC PHD to ensure the system is both ready and affordable. Her email address is courtney.kawazoe@navy.mil.

Alex Nguyen graduated from the University of California, Berkeley in 2014 with a Bachelor’s of Science in Business Administration and a Minor in Public Policy. Currently, Alex is a Logistics Management Specialist at NSWC PHD. Throughout his career with NSWC PHD, Alex has worked with various programs such as the Optical Dazzling Interdictor, the U.S. Navy and the Ship Self-Defense System from both an acquisition and sustainment perspective. His work has resulted in more effective and affordable product support for the U.S. Navy Enterprise and the Warfighter. His email address is alex.nguyen1@navy.mil.