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A ROLE FOR GENERAL PURPOSE SIMULATION IN CAMPAIGN-LEVEL OPERATIONAL MODELING

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ABSTRACT

Military operational and other system-of-systems analysis efforts are usually facilitated by using highly complex and expensive capability-focused simulation models. For studies in which the principal elements of analysis focus on readiness, responsiveness or operational presence rather than kinetic effects and entity interactions, models derived from general purpose simulation applications may provide a better balance of cost and stochastic fidelity than detailed high-resolution simulations or spreadsheet-based analytics. This case study explores USCG cutter operational presence modeling in use, from large-scale campaign simulation and point-solution models to a general-purpose simulation implementation.

1 INTRODUCTION

Force structure analyses provide military organizations with assessments of the relative mission performance of fleet system of systems alternatives. When these studies consider new capabilities, operational concepts or tactics, highly complex, simulation-based models are normally required to provide insights into the operational effectiveness of the candidates. When these studies are an assessment of local and global capacities of the systems (e.g. fleet size, basing or deployment options), a reasonably-robust suite of analytical models can provide comparative insights through point estimates, provided the stochastic factors impacting the decision space are minor.

For operational forces that are relatively vulnerable to unplanned maintenance events (reliability and mishap related) and environmental factors, point-solution analytical models can lead to an increased level of risk when used to inform force structure decisions. High-resolution simulation models can be adapted for force structure modeling purposes. However, the level of detail that makes them very useful in high-resolution operational modeling typically imposes costs in pre-processing effort and runtime resource management, making them expensive or time consuming to use in large scale (campaign level) studies.

In many force structure and other high-level analyses, stochastic fidelity is an important consideration, but alternative capabilities are either comparable or their differences can be adequately accounted for using low-resolution methods. In these cases, relatively low cost, highly adaptable general-purpose simulation modeling (GPSM) may provide a satisfactory and much more time and resource-efficient solution. Studies in which the principal elements of analysis focus on readiness, responsiveness or operational presence rather than kinetic effects and entity interactions are good candidates for a GPSM approach.

2 COAST GUARD OFFSHORE FORCE STRUCTURE ANALYSIS

In 2002, the Coast Guard awarded a multiyear contract to a consortium of Lockheed-Martin and Northrup-Grumman for the recapitalization of the aging offshore cutter and aircraft force under the general term of "Deepwater". The industry team proposed a solution incorporating a system-of-systems approach intended to deliver a replacement capability of equal or better effectiveness at lower cost than an asset-for-asset replacement strategy. Critical support for this approach requires the ability to verify the synergy and efficacy of the less numerous air and surface assets under more efficient and effective command and control. This was originally provided by the Deepwater Maritime Operational Effectiveness Simulation (DMOES), a campaign-level constructive simulation model. DMOES provided the capability to evaluate the Deepwater force structure against 63 measures of effectiveness (MoE) in the offshore regions of Northeast, Southeast, Western and Alaska.

Refined over the years and renamed the Coast Guard Maritime Operational Effectiveness Simulation (CGMOES), this application has served as the solitary modeling capability up to the present for any large-scale fleet mix analysis of the offshore system. As might be expected, the model itself is extremely large, complex and resource intensive, both in terms of time and infrastructure. It requires considerable Coast Guard domain knowledge and experience to run successfully. The large operating and human capital costs of this model were justified by the fact that the capability mix of the system-of-systems was still evolving until fairly recently. However, among the new cutters, the construction of the National Security Cutter class is nearing completion, the Fast Response Cutter class is well-along and the contract for design and construction has been awarded for the last new capability, the Offshore Patrol Cutter. Consequently, the Coast Guard's analytical needs for acquisition support are shifting from detailed performance assessments of system of systems alternative capabilities to force structure and other analyses related to system capacity.

3 CUTTER PRESENCE ANALYSIS MODELING

USCG Offshore Force Structure studies conducted from 2012 onward included a complementary analysis of cutter patrol presence in distant operating areas enabled by the different alternative fleet mixes. Derived from spreadsheet-based analytical modeling, the presence analysis provided valuable context to the ebb and flow of MoEs as a result of fleet changes. The cutter force provides the key enabling capability for most offshore mission efforts other than Search and Rescue and cutter presence and mission effectiveness have a high degree of positive correlation.

Modeling focus has now shifted from research and design of offshore mission capability to one of maintaining and managing the system's mission capacity during the transition from legacy to new systems. Analysis is needed to evaluate candidate capability "roadmaps" to ensure the transition is executed economically and without unacceptable capability gaps in certain regions in particular years. As these types of analysis do not require the higher resolution of capabilities provided by the operational effectiveness models and are becoming more frequent due to higher variance in the operational (vice acquisition) budget profile, presence modeling is becoming a principal tool rather than useful adjunct for decision support.

4 CURRENT MODEL PORTFOLIO AND PERFORMANCE

The current version of CGMOES is an extension of the Naval Simulation System (NSS), originally developed to support high-resolution mission-level analyses for the U.S. Navy and now optimized for Coast Guard campaign-level analysis. The CGMOES extension automates control functions to standardized input files and adds the environmental modeling functionality critical for assessment of platform mission performance. The resulting model delivers high modeling fidelity and full-spectrum measures of performance and effectiveness at the level required, but not without cost: a typical CGMOES study consumes around 350 man-hours in development of operating schedules and input files, verification and validation (V&V) of modeled scenarios and post-processing results synthesis and 40 – 50 million seconds of CPU time in production runs.

The current Coast Guard Cutter presence modeling capability is a mélange of Microsoft Excel tactics and geography modeling worksheets that take a cutter annual schedule as input and provide point solution estimates of time spent in theater (including mid-patrol breaks for rest and replenishment) and time spent actively patrolling. The model results are an amalgamation of expected values that consider the major performance drivers of speed, patrol leg endurance and seakeeping, but do not incorporate any Monte Carlo features. It has the virtue of being very fast (virtually instantaneous) and easy to operate. However, it relies upon a fearsome list of assumptions, changes to any of which require a deep-dive into cell formulas and a difficult verification and validation (V&V) effort. To date the model has been used only to provide complementary context illustration for the mission effectiveness modeling.

5 GPSM-BASED CUTTER PRESENCE MODELING

The shift in emphasis from a background contextual to a more decision informational role requires the presence modeling to incorporate better fidelity in incorporating stochastic factors affecting cutter effectiveness. Specifically, the legacy fleet has generally lower seakeeping capability, which increases transit times to and from patrol, and decreased reliability due to advanced age (legacy cutter fleet average age is 41 years). To provide a better representation of the risks associated with the variance in performance between legacy and new cutters, we have developed a GPSM analysis capability using ExtendSim. With an identical effort in the preprocess annual schedule development and only a nominal increase in processing time (from virtually zero to less than one minute on a single CPU), the model delivers not only presence central point estimates, but relevant dispersion statistics as well.

The model has two main working components: a regional weather update function and a cutter patrol modeling capability. At twelve-hour intervals, the weather function generates an entity that samples from seasonal empirical distributions and updates the current sea state condition in each patrol area. The patrol function generates entities representing cutter patrols via the annual schedule input file. These entities transit from the cutter homeport to the designated patrol area at a speed appropriate to the class of cutter and the current sea state conditions en route. Every twelve hours in the patrol area, the cutter checks the local weather and updates its ability to operate deployable small boat and aircraft, accumulating time spent as full mission capable (FMC) or in degraded operations (because of sea state). At appropriate intervals, the cutter breaks off patrolling to transit to a local logistics port for rest and replenishment periods. The cutter continually updates its time remaining variable and departs the patrol area at a time estimated to allow return transit to its homeport by the end of the scheduled patrol period. The patrol operations include randomly-generated mechanical breakdowns appropriate to the cutter class. The model tracks total operational cutter time in each theater and patrol area, broken down by FMC/Degraded and the helicopter type embarked. The model also collects statistics on patrol efficiency for each cutter, defined as the ratio of annual FMC on-station time to total annual patrol time.

6 RESULTS AND FUTURE WORK

The GPSM patrol presence modeling capability provides insight into operating capacity in critical operating areas, facilitating the assessment of alternative force structures, both in standalone analyses and for alternative culling in more intensive operational effectiveness studies. The presence metrics also furnish the basic inputs needed to support future metamodeling of operational effectiveness. Finally, organization of the output metrics by individual cutter enables the development of cutter utility measures useful in guiding roadmap decisions.

The GPSM concept incorporates the relevant environmental and logistical factors at a greatly reduced cost in setup, V&V and pre- and post-process efforts, enabling significant improvements in turnaround time and throughput. The adaptability of the modeling approach is currently being proven in support of a comparative analysis of manned and unmanned Maritime Patrol Aircraft for Coast Guard Intelligence, Surveillance and Reconnaissance missions. This case provides a useful proof-of-concept for economical application of a GPSM for selective high-level modeling efforts of extremely complex operational systems.