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Integrating Cost as a Decision Variable in Wargames

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The US military can no longer afford to be reactive, leaving critical cost analyses to the months and years following operations or full-scale conflicts. By leveraging cost in wargaming, as part of the Joint planning process, the Department of Defense (DOD) can provide Congress and the American taxpayers a range of potential costs associated with various military engagements. If senior leaders can consider costs as part of effectiveness analyses during wargames, they can provide more fully informed decisions reflecting fiscal and operational realities.

Resilient and Agile Logistics

Wargames serve a critical function in preparing the United States Air Force (USAF) for future wars and conflicts. They immerse decision makers in a realistic environment in which wartime decisions are tested. Data from stress tests of feasibility, current concepts of operations, risks of innovative design solutions, and other effectiveness measures provide decision makers the necessary information to enable the military to stay ahead of its adversaries.[1]

Achieving these desired outcomes requires robustness and realism in the simulation. The 2018 Task Force on Survivable Logistics found that one element of realism—logistical constraints—was lacking in wargames.[2] In its findings, the task force recommended the military departments develop new integrated wargames "with the logistics fidelity to identify logistics constraints to operations."[3]

The 2018 *National Defense Strategy* provides additional evidence regarding the importance of resilient and agile logistics, calling DOD investment imperative.[4] One way the Air Force is addressing these needs is through the development of the Integrated Sustainment Wargaming and Analysis Toolkit (ISWAT). The goal of the toolkit is to provide defensible, long-duration logistics and sustainment wargames and analyses. While ISWAT fills the previously identified logistics wargaming gap, the current version lacks fiscal considerations to create the realistic environment senior leaders need to make fully informed decisions.

Incorporating cost as a factor in evaluating wargame outcomes is a novel change to the current state of wargaming. Why are costs important? As John G. Vonglis, former Assistant Secretary of the Air Force (Financial Management and Comptroller) stated, "in a constrained fiscal environment, our ability to provide accurate, timely, and relevant financial data, from cost estimates to budget projections . . . is paramount to enabling Air Force leadership at all organizational levels to make informed decisions."[5] To be clear, this article does not suggest cost should be the primary decision criterion. Rather, senior leaders' consideration of cost in conjunction with effectiveness analysis provides the ability to make more fully informed wargame decisions.

This article explains how to integrate cost as a decision factor into a wargame platform using the ISWAT platform as a proof of concept. But incorporating costs into ISWAT does not come without complications. For example, the Department of Defense does not have an approach to estimating wartime flying-hour costs. Rather, flying-hour costs are calculated under an assumption of peacetime. This approach is problematic as prior research suggests wartime and peacetime costs differ.[6]

Thus, to fully develop credible cost models for ISWAT, several questions must be answered: (1) Which cost elements are relevant to wargame scenario modeling? (2) Which cost elements vary based on wartime engagement, and how can this variation be modeled? and (3) How can cost be compared relative to effectiveness in wargaming? This article seeks to answer these questions by examining the development of cost models for the ISWAT wargaming platform, the results of which serve as a road map for incorporation in other USAF wargaming efforts.

History of Wargaming

While wargaming has its roots in traditional games such as chess and Go, modern wargaming was not introduced until the 1800s. Just as Prussian general

Baron von Steuben introduced drill and ceremony to the United States at Valley Forge, Prussia is also credited with introducing the United States to wargaming.[7] Modern wargaming is generally considered to have been developed by Prussian nobleman George Leopold von Reisswitz in 1811, and further refined by his son, George Heinrich Rudolf Johann von Reisswitz—an officer in the Prussian army—in 1824.[8] This game, titled *Kriegsspiel*, was subsequently translated into English and adapted to US war strategy by Major W. R. Livermore in 1833.[9] Modern wargames have developed substantially since this point; however, much of the published research tends to focus on specific scenarios or on the development of new models such as the defense of the Baltics, defense of the homeland, or next-generation war-gaming for the US Marine Corps.[10]

Generally, the literature lacks research accounting for additional variables in wargames. One notable exception, as previously discussed, is the recent incorporation of agile logistics as a focus of the ISWAT wargame. Several prior research efforts have supported the development and incorporation of logistics into ISWAT.[11] These efforts have identified cost and budgets as important factors that *should* be considered in the logistics wargame, but thus far no specific cost research *has* been produced.

The omission of cost as a consideration in wargames is nearly ubiquitous. A literature review found only one mention of "cost of war" being included in wargames. This occurred in the 1960s, championed by then-Secretary of Defense Robert S. McNamara, whose goal was to achieve effective defense at a sustainable cost point.[12] Thus, the inclusion of cost as a decision factor in wargames provides a unique contribution to the current wargaming body of knowledge.

Analysis Tactics and Decision-Making Protocol

The first step in including costs in wargames is determining which aspects of the wargame are relevant and should be costed. While this step may seem trivial on the surface, the practical application is quite difficult. The universe of potential cost elements includes not only the obvious candidates such as fuel or aircraft maintenance, but also buildings, personnel casualties, and runway repair. Additionally, reasonable arguments to include or exclude crew manpower can be made. One could argue we pay for the manpower regardless so it should be excluded, but crew manpower is also a direct cost incurred during the wargame so the argument for inclusion is equally compelling.

To resolve these conflicts, ISWAT subject matters experts were brought in to identify those costs deemed most relevant. To guide the decision-making process, the team focused on operating and support (O&S) and manpower costs characterized by variability based on wargame decisions. Through these discussions, five major cost categories were identified as critical: aircraft operations, fuel, munitions, unexploded ordnance (UXO) removal, and runway damage repair. A brief explanation of the cost methodology for four of these elements is provided below. (Fuel as a cost category is straightforward.)

Aircraft Operations

Aircraft operations represent the largest costs not only in ISWAT but in most Air Force wargames. The Office of Cost Assessment and Program Evaluation (CAPE) publishes a standard cost element structure (CES) the Air Force utilizes to collect and organize O&S data.[13] Each element of the CAPE CES was analyzed in conjunction with inputs from Air Force Materiel Command's Directorate of Strategic Plans, Programs, Requirements, and Assessments (A5/8/9) SMEs to identify the specific elements relevant to wargames. Table 1 contains a list of these cost elements and their inclusion or exclusion (italic elements are excluded; bold elements are included). Additionally, the data source and a brief description of the methodology are provided for each element.

Table 1. CES inclusion/exclusion and methodology overview

CES	Data Source	Reason For Exclusion/Methodology
1.0 Unit-Level Manpower	N/A	N/A
1.1 Operations	AFI 65-503 Table A36-1	Multiply Aircrew, aircrew ratio, FY 2020 Composite Rate, FY 2020 Hourly Rate
1.2 Unit-Level Maintenance	LCOM	Manpower requirements by rank per aircraft times FY 2020 Composite Rate, FY 2020 Hourly Rate
1.3 Other Unit-Level	N/A	Includes support costs, we focused on operational costs
2.0 Unit Operations	N/A	N/A
2.1 Operation Material	N/A	N/A
2.1.1 Energy (Fuel)	AFI 65-503 Table A13-1/DLA	Multiply hourly consumption by DLA JP-8 fuel cost
2.1.2 Training Munitions and Expendable Storage	N/A	Training munitions non-differentiable from expendable stores
2.1.3 Other Operational Material	N/A	No specified costs, misc catch all
2.2 Support Services	AFTOC	3 year historical average divided by flight hours
2.3 Temporary Duty	N/A	TDYs typically do not occur during deployments
2.4 Transportation	AFTOC	3 year historical average divided by flight hours
3.0 Maintenance	AFI 65-503 Table A4-1	Given vales for GSD, MSD, and CLS plus wartime cost increase

Table 1. (*continued...*)

	CES	Data Source	Reason For Exclusion/Methodology
3.1	**Consumable Materials and Repair Parts**	N/A	Included in 3.0
3.2	**Depot Level Reparables**	N/A	Included in 3.0
3.3	**Intermediate Maintenance (External to Unit-Level)**	N/A	Included in 3.0
3.4	**Depot maintenance**	N/A	Included in 3.0
3.5	*Other Maintenance*	N/A	Included in 3.0
4.0	Sustaining Support	N/A	N/A
4.1	*System Specific Training*	N/A	Costs incured regardless of wartime engagement
4.2	**Support Equipment Replacement and Repair**	AFTOC	3 year historical average divided by flight hours
4.3	*Sustaining/Systems Engineering*	N/A	Costs based on age of aircraft and not usage rate
4.4	**Program Management**	AFTOC	3 year historical average divided by flight hours
4.5	**Information Systems**	AFTOC	3 year historical average divided by flight hours
4.6	**Data and Technical Publications**	AFTOC	3 year historical average divided by flight hours
4.7	*Simulator Operations and Repair*	N/A	Costs associated with training only
4.8	*Other Sustaining Support*	N/A	Costs not tied to a specific element
5.0	*Continuing System Improvements*	N/A	Costs not driven by wartime engagement
6.0	*Indirect Support*	N/A	Not direct system costs

With the relevant aircraft cost elements identified, the team then determined a wartime cost of operation. Previous literature found operational costs during wartime vary from peacetime, but the literature failed to recommend methodologies to calculate these costs at the CES level.[14] One solution would have been to identify a true deployed cost per flying hour by dividing the deployed cost by the number of deployed flying hours. But while deployed costs are easily obtainable, the Air Force does not formally track associated deployed flying hours in an unclassified centralized repository.

The solution to this problem was to derive a wartime cost by analyzing aircraft operating costs before 9/11 in comparison to costs after 9/11. First, the team reviewed the data and saw a large spike in operating hours in 2002 and 2003 compared to prior years, indicating the hypothesis of a pre- to post-9/11 change due to wartime had merit. The team verified this conclusion through statistical testing.

Next, the team utilized regression analysis to identify the difference in cost between peacetime and wartime flying hours. More specifically, the team employed regression analysis on O&S data from the Air Force Total Ownership Cost database where the fiscal years 1999–2001 were considered analogous to peacetime, and the fiscal years 2002–03 were analogous to wartime. These regression results provided a dollar value that was added to the relevant cost elements in table 1.

One of the largest benefits of using the CAPE CES in the methodology was the ability to tailor the analysis. By delineating costs at the lowest level possible, costs could be included or excluded with great granularity. This specificity allowed for a large degree of flexibility in wargame cost analysis. In initial tests of this ISWAT cost model, senior leaders requested "what-if" analyses examining only so-called marginal costs, defined as those CES elements from table 1 that represented only the expendable items from the wargame. Through discussion with SMEs at Air Force Materiel Command A5/8/9, the relevant CES elements (CES 2.1.1 *Fuel* and CES 3.0 *Maintenance*) were identified and calculated as marginal costs. While this represents only one example, the flexible structure of this method allows for numerous future "what-if" scenarios.

A second example of this flexibility is the comparison of use rates of aircraft employed in the wargame with aircraft not used in the scenario. This analysis also came from discussions with senior leaders during the early testing of the cost model. The purpose of this analysis was to attribute cost only to those hours accrued during the wargame that exceeded hours operated if the wargame had not occurred. The team obtained this specific data by multiplying the number of wargame days by the peacetime cost per flying hour of the aircraft and the average number of hours used per day. The wargaming cost of the aircraft was then subtracted.

Additionally, this method can be used to gauge if deployments to the theater are appropriately sized. If use rates are substantially lower than those at home stations, it follows that assets may be at increased risk of destruction due to aircraft spending more time on the ground.

One last example of the flexibility this methodology affords is in transportation costs. The transportation costs (CES 2.4 *Transportation*) were calculated on a per total flying hour basis; however, they could also be calculated based on the resupply rate. Since ISWAT generates a time-phased force deployment document for supplies needed, pallet positions, and required aircraft for transport, transportation costs can be calculated by multiplying aircraft flying hours for supply missions by the calculated wargame cost per flying hour.

Munitions

Munition costs are an obvious expense associated with wartime engagement, but components of munition costs are quite different from those of an aircraft. Whereas aircraft have a large O&S cost, munitions do not. Rather, the procurement cost of munitions expended in the wargame is of interest. Therefore, the team utilized the average procurement unit cost metric as its calculation. Average procurement unit cost is the total procurement cost divided by the number of units employed in the wargame. This calculation removes any O&S or indirect costs and represents what it would cost to replace a weapon after its employment.

Data sources to calculate munition average procurement unit costs were not as readily available as aircraft operational data. To the maximum extent possible, authoritative DOD sources were used, and selective acquisition reports were the primary sources. In those instances where selective acquisition reporting was not required for the munition program or not available for a munition, the team obtained information directly from the specific munition program office. These data came in the form of recent cost estimates, but due to unavailability, some average procurement unit costs had to be collected from non-DOD sources such as Defense Industry Daily.

Unexploded Ordnance

A less obvious cost of wartime engagement is the cost of UXO removal. Unexploded ordnance removal was calculated in two parts—equipment costs and manpower costs. Equipment costs were calculated by the composition of unit type code equipment lists and use rates provided by explosive ordnance disposal SMEs. The unit type code equipment consisted of items such as time blasting fuses, blasting caps, and shock tubes. Manpower costs were calculated based on the average composition of two explosive ordnance disposal unit type codes.

Runway Repair

Another important cost in wargames is runway repair. The basis of cost for this element is the Rapid Airfield Damage Recovery system. Rapid airfield damage recovery simultaneously performs as many runway repair functions as possible. While these repairs are rapid, they are not permanent. Each repair can handle a different number of total takeoffs and landings (e.g., 100 or 3,000).[15] For ISWAT analysis, the team calculated an average of these repair types (100 and 1,000 takeoffs/landings) as the basis for cost. The costs for runway repair were calculated in three categories: materiel, fuel, and manpower. Equipment costs are excluded, as these costs are applicable across multiple wargames.

Cost and Mission Effectiveness Tradeoff

Once a wargame is completed, important insights can be garnered through the postgame analysis. The cost models presented in this article are intended to be used primarily in this phase of the wargame. While cost is directly measurable, the measures of effectiveness are designed to support the decisions of a senior leader during a wargame and can be measured by different metrics.[16] To investigate the relationship between overall wargame cost and effectiveness, the data were plotted on a graph with cost on the x-axis and effectiveness on the y-axis. The team then overlaid on the x-axis a stacked bar chart with a section of each column for the major cost categories. The analysis of this graph was also aided by the inclusion of a threshold and objective effectiveness line. An example of this graphic using notional data is shown in figure 1.

This variability in effectiveness measures provides flexibility to tailor the wargame to the specified objectives of each unique wargame and can be applied in future wargames at the tactical level, evaluating the use of an individual weapon system. In the case of figure 1, the F-35 has been drawn out as a section of aircraft costs. If there was an option to use the lower-cost F-16 instead of the F-35 for some of or all these hours, the outcome of potential cost savings on effectiveness can be analyzed.

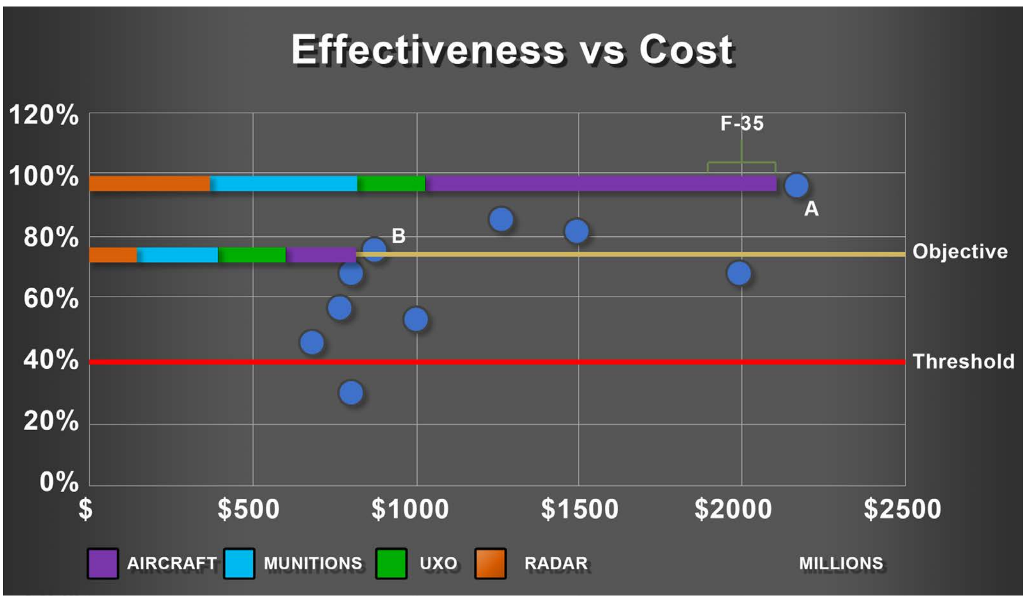

Figure 1. Effectiveness vs. cost-notional graph

Additionally, wargames can be compared to each other at a strategic level. For those points that fall above the yellow objective line, the wargames were considered effective. But bringing cost into the equation may result in the outcome being viewed differently. For example, as shown in figure 1, the most effective outcome (96 percent) costs $2.2 billion (Point A). The objective effectiveness (75 percent) could have been achieved at a cost of only $0.7 billion (Point B). The decision maker can then decide whether the additional $1.5 billion is worth the additional 26 percent of effectiveness.

Those points falling between the red threshold line and the yellow objective line provide another opportunity for analysis. These points represent wargame decisions that met a minimum effectiveness standard but fell short of the effectiveness target. Points that fall in this region should be analyzed to find the most cost-effective decision. Those points that fall below the red line represent wargaming decisions that most likely missed the intent of the wargame and can thus be discarded from the trade-off analysis.

Changes to the status-quo mode of operation often require a crisis or watershed event. Recent wargaming events are providing that window of opportunity. Vice Chairman of the Joint Chiefs of Staff General John E. Hyten highlighted the need to reexamine war-fighting concepts after a high-profile wargaming exercise loss in October 2020.[17] One of the changes Hyten noted was a desire to move away from aggregating forces to a new concept dubbed "expanded maneuver." The range of possible alternatives to pursue the expanded maneuver concept is undoubtedly vast, and the associated costs of these options are likely to vary widely. Implementing a cost-effectiveness analysis of these alternatives can inform decision makers during their tradeoff analyses. Thus, the window of opportunity for major changes in wargame concepts (such as expanded maneuver) is also an opportunity to consider more seriously other decision variables such as cost in wargame analysis.

Conclusion

To date, this research represents the first inclusion of cost in wargaming analysis. Despite being an initial examination into wargaming costs, the research has several key implications. First, the cost methods developed can be used to study the aircraft, munitions, unexploded ordnance, and rapid airfield damage recovery costs of each wargame, as well as aircraft use rates. These costs can be used to identify cost drivers. For example, analysis may determine the distance between the US military's center of gravity and the enemy's center of gravity is a good predictor of cost. These cost drivers can in turn be used to predict costs of future conflicts. This same idea can be used for effectiveness.

Second, the comparison between cost and effectiveness stimulates important tradeoff discussions. The model allows for a larger analysis between wargames.

Comparing the effectiveness of decisions in a wargame can now be quantified where cost is considered as one of the decision variables. Certainly, there are potential limitations to this analysis. If it is decided after the wargame that cost savings were available, and the wargame is rerun considering these cost-saving measures, the effectiveness of that wargame may be reduced further than the relationship between cost and effectiveness may suggest. This reduction would most likely be caused by unanticipated secondary effects such as fuel usage causing a change in aircraft availability; thus, careful considerations are needed when selecting the criteria for measuring effectiveness.

Third, current postgame wargame analysis has been tempered by a sensitivity to the assumptions and limitations of the specific wargame scenario. Undoubtedly, these insights have been highly valued as demonstrated by a single wargame platform spending millions annually for wargame analysis support, but the extant postgame analysis has been limited by the variables analyzed. Bringing the ability to discuss costs in concert with the traditional analysis opens the door for more strategic, long-term applications. The incorporation of cost in wargames can influence Air Force doctrine and can potentially inform strategic decisions in the program objective memorandum *prior* to wartime engagement. These are the types of paradigm-changing insights that have yet to be fully realized through wargaming.

The US military can no longer afford to be reactive in its cost analysis, providing Congress and the American taxpayer with postconflict cost reports. The Department of Defense should instead be proactive in its cost planning. By leveraging cost in wargaming in the Joint planning process, the Department can provide Congress and the American taxpayer a range of potential costs associated with entry into a power competition or conflict or the cost of a tactical or operational engagement.

Additionally, leveraging cost in wargaming allows the military to analyze the cost of conflict as a friendly center of gravity, which, in turn, avoids force culmination due to fiscal constraints. This same logic can also be applied to adversaries' centers of gravity, enabling the military to analyze the impacts of concepts like Joint all-domain operations and expanded maneuvers on enemy fiscal constraints and restraints.

Incorporating cost as a decision variable in wargames opens additional avenues for future research. The main benefits of cost analyses may not be related to the cost or features of a specific weapon system but rather the delivery of a specific capability. Thus, the potential for future research is to develop cost models for capabilities rather than weapon systems. This approach would uncouple wargame costs from the costs of developing a new model for each new aircraft, munition, or a new method of runway repair. Instead, these models would allow for the cost of stealth air superiority regardless of whether that capability is offered by a current airframe or a future F-XX still to be developed.

Other questions for future research include: How would wargaming analysis change with the inclusion of more costs? How would the model change if the research were conducted at a higher level of classification? These questions open the door to a wide variety of future research to improve the integration of cost into wargaming. The exploratory analysis provided in this article was just the first step of the journey. The door is now open to consider cost as a decision variable in wargames. Through future research and discoveries, the knowledge needed to improve wargaming is possible. ✪

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