Operational Readiness Rollup

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Operation EAGLE CLAW was the abortive 1980 mission that failed to rescue the American hostages in Tehran. Wayne Hughes, a retired US Navy captain and Professor of Practice at the Naval Postgraduate School (NPS), describes how EAGLE CLAW, which required six helicopters for success, was the poster child for bad readiness planning. “Reliability of each aircraft was estimated to be 75%,” says Hughes, “so one might assume that eight aircraft would be enough because 75% of 8 is 6.” But that doesn’t mean that the required six would survive. Had the planners known to look up the binomial distribution, they would have been shocked to learn that starting with eight aircraft provided only a 68% chance of success for one of the most important postwar military missions in US history. Fellow NPS Professor of Practice Jeff Kline uses the EAGLE CLAW case study to introduce NATO senior leadership to best, or in this case worst, practices in risk assessment. Kline’s PowerPoint deck is available at https://www.probabilitymanagement.org/s/Quantitative-Risk-Assessment_NATO_12Aug2012-UD.pptx.

By 1990, Monte Carlo simulation packages running within spreadsheets were readily available for this sort of analysis. However, it still might not have been applied in an operation as secret and stovepiped as EAGLE CLAW. First, specialized software was required, and second, operational planners may not have had the training to know what sorts of input distributions to use. Within the past few years, native Microsoft Excel has become powerful enough to perform interactive simulation without any additional software through improved performance of the Data Table function (Savage, 2012, 2016).

Now that simulation is universally available, it is often the method of choice over theoretical estimates like the binomial distribution that might have saved EAGLE CLAW. This is because in the real world there will usually be complicating factors. For example, helicopter equipment failures will not occur independently when overloaded helicopters are operating together in sandstorms or at high temperatures. An interactive Data Table simulation of operation EAGLE CLAW is available at https://www.probabilitymanagement.org/s/EagleClawSimulation.xlsx. You may specify the reliability of the aircraft, the number starting the mission, and the number required. Furthermore,

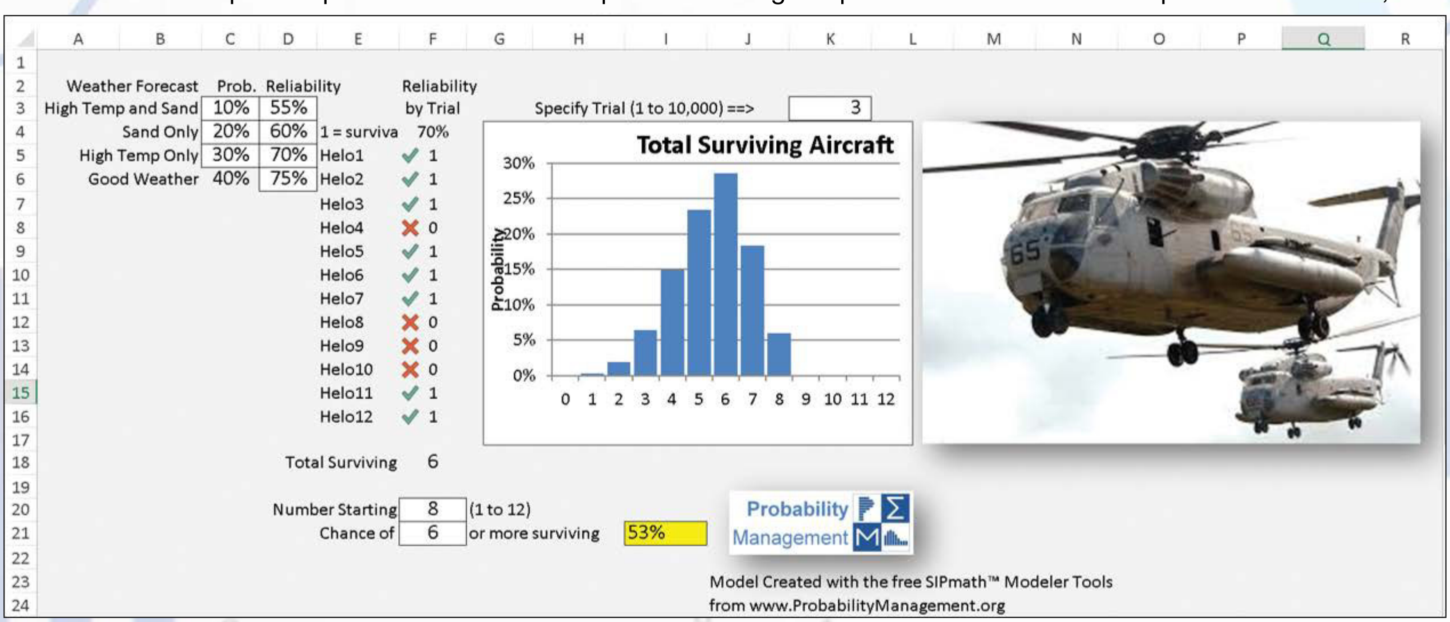

Figure 1. Helicopter survival readiness model.

you may experiment with degradation under different weather forecasts. With each keystroke, the model instantly runs 10,000 trials and reports the chance of having the required aircraft operational. This model is shown in Figure 1.

Rolling Up Readiness

Even free, lightning-fast simulation in every spreadsheet does not provide planners with the knowledge to generate the appropriate random numbers. Recently, analogous standards have emerged for conveying the inputs and outputs of simulations (Savage and Thibault, 2015). The discipline of probability management is based on storing the outputs of simulations in arrays called stochastic information packets (SIPs). These may be aggregated with other SIPs or used as inputs to other simulations. This reduces the statistical knowledge required by decision maker(s), and, more importantly, allows operational readiness to be rolled up from level to level.

Suppose, for example, we have simulated that squadron A has a 60% chance of accomplishing a particular mission. A separate simulation shows that squadron B has a 70% chance of success for the same mission. Does that mean that if we send both squadrons, there will be a 130% chance of success? No, that can't be right. A more complex simulation that incorporates both squadrons may not be possible if the two simulations were developed by different teams in different locations. You may be headed toward an ever-growing simulation model that collapses under its own weight. SIPs, on the other hand, from several independently developed submodels, can be "hooked together" on an ad hoc basis for agile planning purposes.

We have created interactive notional simulations of weapon assets that are combined with a model of communication reliability and then rolled up to create a high-level engagement dashboard (see Figure 2). These models may be downloaded at https://www.probabilitymanagement.org/readiness. They can be run in native Excel without macros or add-ins.

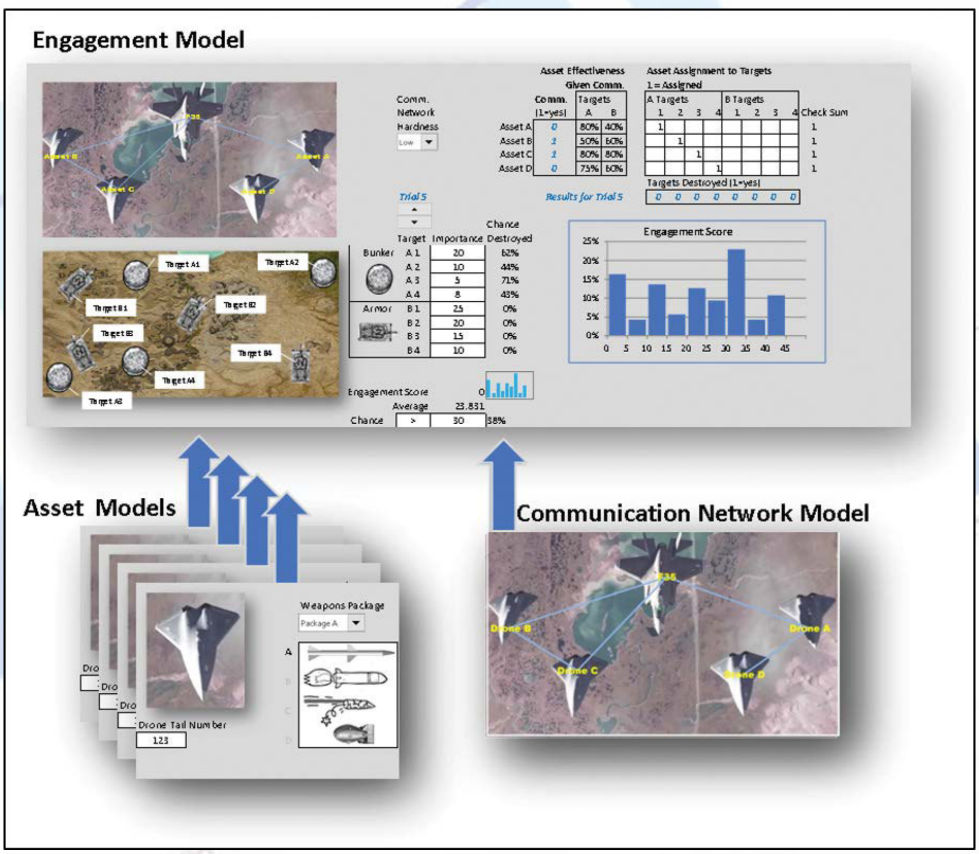

Figure 2. Asset and communications models roll up to engagement mode.

Asset Model

Figure 3 shows the asset model input to this tool. In this model, the user specifies an effectiveness for each of four weapons packages against two target types. The results are simulated with "indicator" variable as hit = 1 and miss = 0 for 1,000 trials. Four assets are simulated for both target types, each with a different weapons package. The results are stored in two SIP arrays for each asset, which are contained in a library to be rolled up to the next level.

Communications Model

The communications model simulates the ability of a manned control aircraft to send commands to each of the four assets defined earlier. Figure 4 shows the interface with this model. The user may specify the network geometry along with the survival probability of each communication link, whereupon 1,000 trials instantly calculate the chances that each drone is connected to the manned control aircraft. Again, we have used indicator variables for each event, with 1 indicating connected and 0 disconnected. These events are not necessarily independent because of the underlying network geometry. Because the resulting SIPs preserve the statistical relationships between variables, they are said to be coherent, and form a stochastic library unit with relationships preserved (SLURP).

This model has been simulated twice, with a link hardness survival probability of 75% and 90%. The resulting SIPs are added to the library already created from the individual

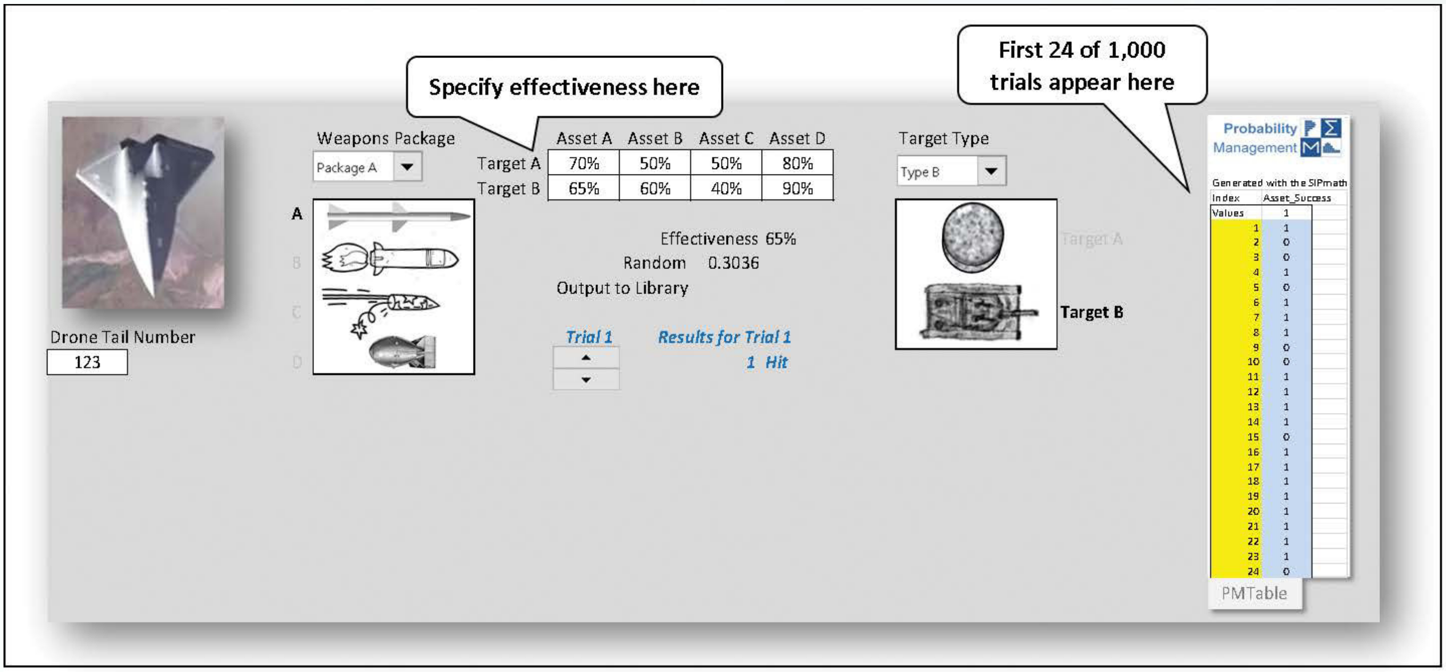

Figure 3. Asset model interface.

asset models, to be rolled up to the engagement model. Figure 5 shows a portion of the resulting SIP library.

The Engagement Model

The engagement model "runs off" the SIPs of the earlier models and could be used by a commander to maximize the effectiveness of targeting in the field. Note that the success of an asset against a target (0 or 1) must be multiplied by another 0 or 1 depending on whether that asset is under control of the command aircraft. The commander must allocate four drones to eight targets in the face of both performance and communication uncertainty. In a real application, mathematical optimization would probably be applied to get the best expected bang per buck. In this version, you have the fun of trying to maximize your weighted engagement score by hand (see Figure 6).

A More Realistic Model

The application of such operational readiness modeling spans all warfighting functions across the range of military operations. In a recent prototype project opportunity notice (PPON) issued by the US Army, the statement of need indicated that, among other things, the Army sought to improve equipment availability and fleet readiness across the force through a predictive tool. An

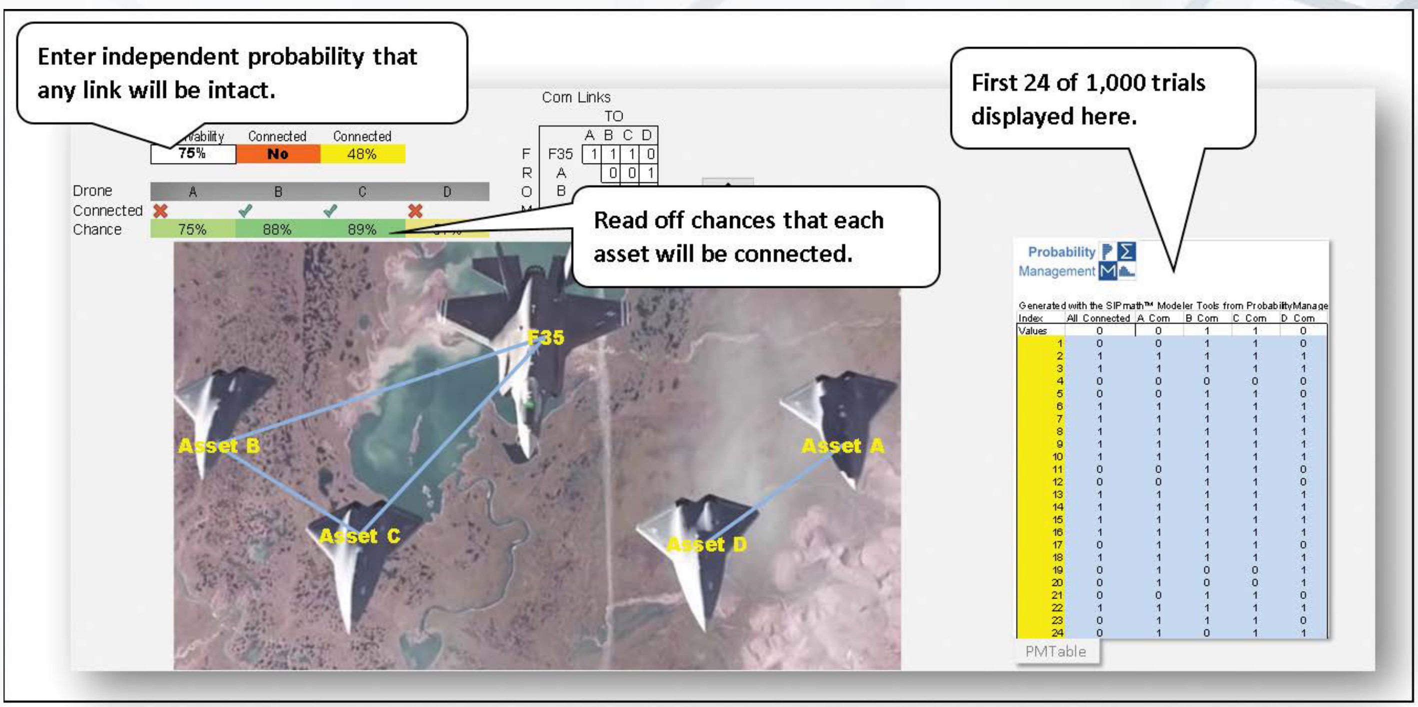

Figure 4. Communication model interface.

	A	B	C	D	E	F	G	H	I
1	PM_Trials	1000							
2	PM_Lib_Provenance	S 12-31-2018							
3									
4				Meta Data	Index				
5				Average	1001				
6	Click [+] to show data								
7			Drone_A_Target_A	Drone_B_Target_A	Drone_C_Target_A	Drone_D_Target_A	Drone_A_Target_B	Drone_B_Target_B	Drone_C_
8		1	1	1	0	1	1	0	1
9		2	1	1	0	1	0	1	1
10		3	1	1	1	0	0	0	0
11		4	1	1	0	0	0	1	1
12		5	1	0	0	0	1	1	1
13		6	1	0	1	1	0	1	1
14		7	1	0	1	1	0	1	1
15		8	1	1	1	1	0	1	0
16		9	1	0	1	1	0	1	1
17		10	1	0	1	0	1	1	1
18		11	1	0	1	0	1	0	1

Figure 5. SIP inputs to communications model.

overarching objective of the prototype project was to develop a prototype solution “capable of incorporating statistically based predictions that will improve tactical units’ equipment readiness, operational availability, and unit decisions for maintenance and supply functions” (PPON, 2018).

In responding to this requirement, we developed a conceptual rolled up tank company model using notional reliability, availability, maintainability, and cost data commonly available from Army data sources. This model meets the intent outlined in the PPON’s statement of need, using realistic, system-level operational availability (Ao) data. It predicts how many of the tanks in a 14-tank company would be available if they had to respond immediately to a mission tasking. We further expanded our analysis in this model to determine the chance of those tanks remaining operational throughout the mission given the observed system-level Ao data. Figure 7 shows the data used in the model.

Although data used in the modeling instance shown here is strictly notional, it represents descriptive statistics based on extensive amounts of actual historical and current system-level maintenance and supply data available for statistical research and analysis. The types of underlying system-level readiness data reflected earlier are readily available for most systems throughout the

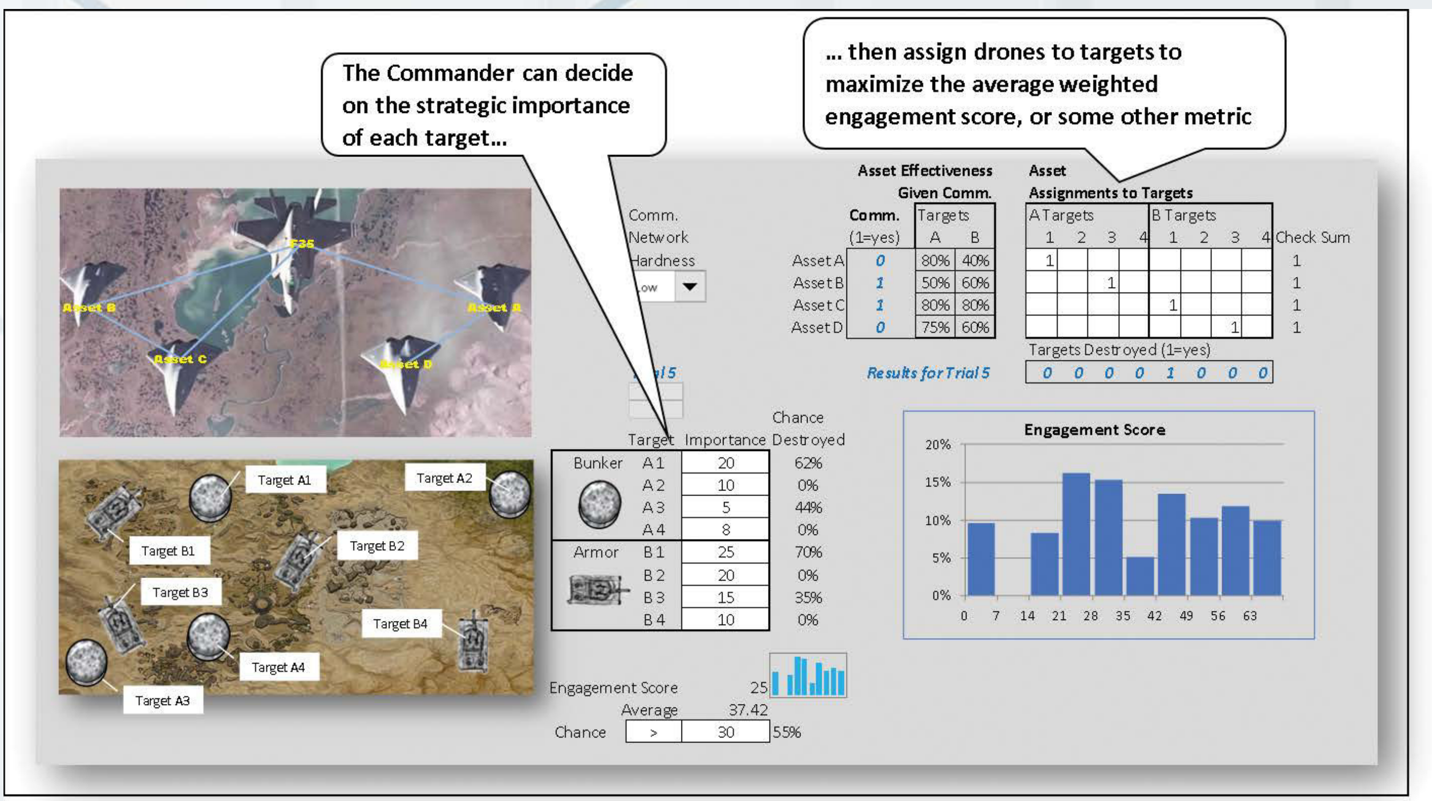

Figure 6. The engagement model.

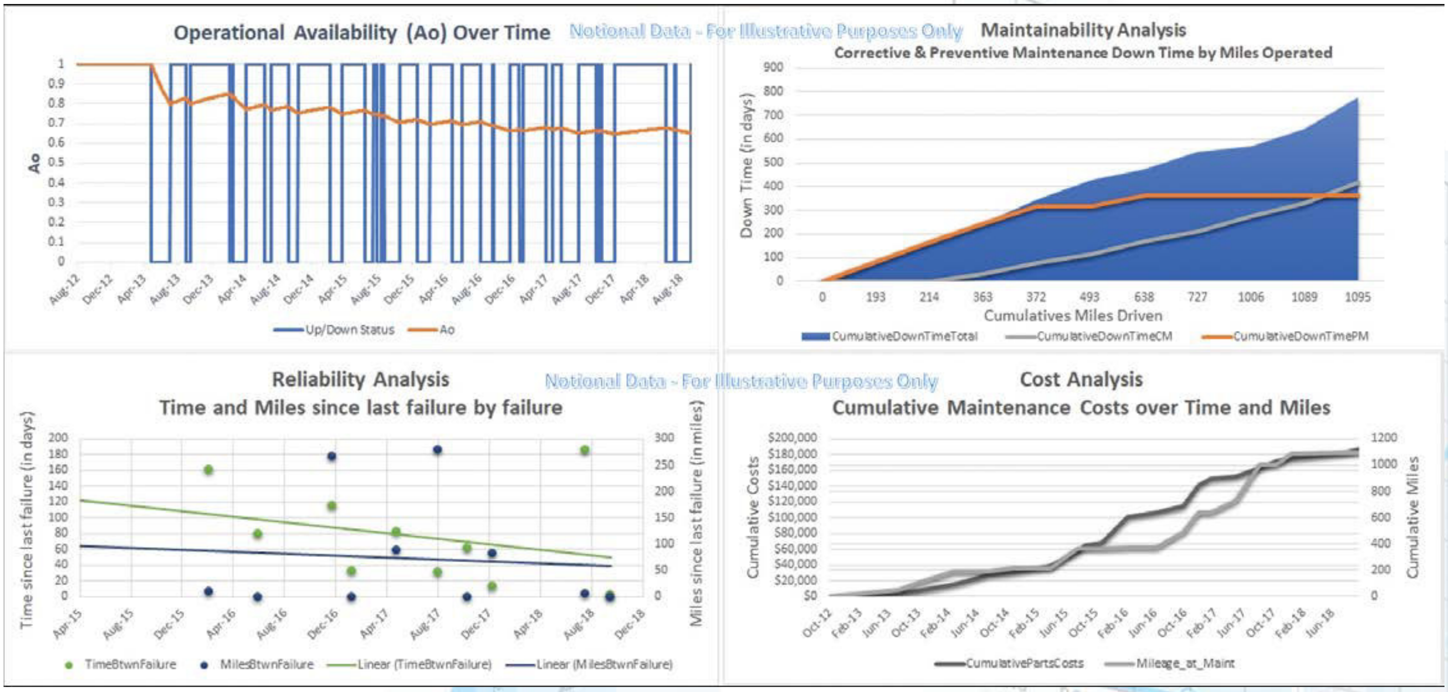

Figure 7. Notional readiness data form tank company readiness modeling.

military. Therefore, operational planners, staff, and commanders are right to expect robust modeling, simulation, and analysis in support of tactical, operational, and even strategic-level readiness assessments.

Figure 8 shows the interface and output of the tank company readiness modeling.

In the previous examples, we leveraged native Excel's improved Data Table function to perform thousands of Monte Carlo simulations per keystroke for useful and relevant assessment of operational readiness without additional software. These recent improvements in our ability to account for uncertainty allow us to rethink the military's approach to readiness. This is of utmost importance in operational planning, which has traditionally not relied on readiness reporting, but could benefit substantially by doing so.

These smaller and simpler models do not replace large-scale discrete event simulations any more than handheld automatic weapons replace artillery. But the ability to quickly construct Lego-block-like analytical models to be rolled up into larger structures has the potential to transform the military readiness discussion and perhaps prevent future EAGLE CLAWs.

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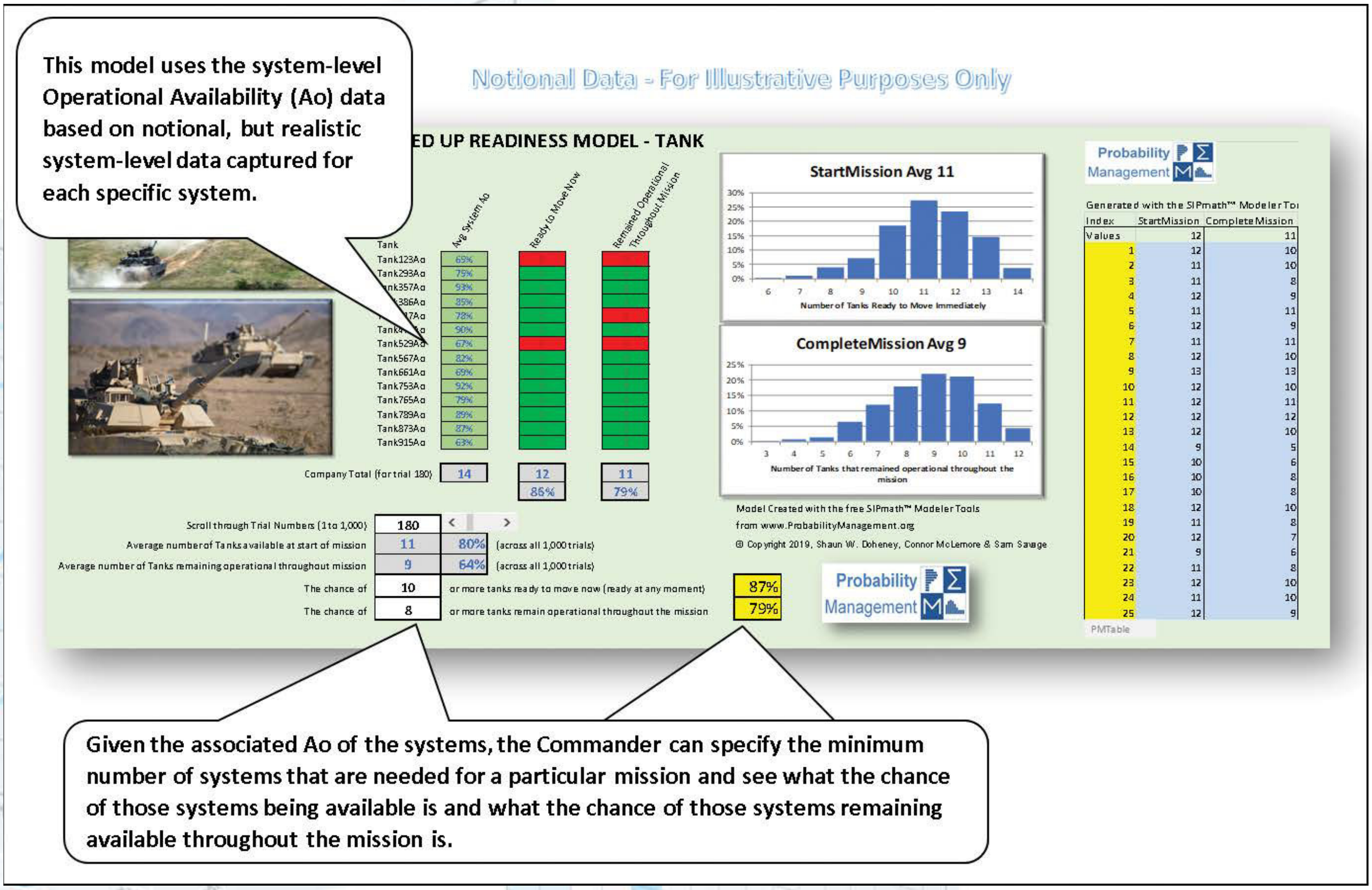

Figure 8. Rolled up tank company readiness model output.

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