Innovation in Logistics

Simulation is more than a training tool

by Capt Michael J. Blankenbeker

Currently, the Marine Corps employs simulation methods and systems primarily as a training tool. Whether in a virtual or constructive environment, these simulated training systems are utilized to stimulate the decision-making process for Marine Corps units, staffs, and leadership. Activities such as the Marine Corps Tactics Operations Group, the Marine Corps Logistics Operations Group (MCLOG), and the MAGTF Staff Training Program accomplish this regularly to great effect. However, training is but one of eight enumerated purposes for simulations in the DOD; the others are testing and valuation, planning, medicine, intelligence, experimentation, analysis, and acquisition.[1] While training systems must continue to be used and improved throughout the Marine Corps, there exist numerous other areas where we should be leveraging our capabilities; one particular system that comes to mind is Logistics Innovation. Additionally, there are numerous methods that could be explored such as virtual/augmented reality in maintenance and healthcare, acquisition performance modeling, artificial intelligence and machine learning, and supply chain experimentation. This article demonstrates the effectiveness and existing potential of using discrete-event simulation (DES) to solve supply chain problems. Unlike some innovation articles which explore and extrapolate pre-mature concepts, often not ready for mainstream use, this article specifically addresses center-of-mass challenges that have long plagued the Marine Corps logistics network.

>Capt Blankenbeker is an 0402 trade, currently holding the billet of Modeling and Simulation Officer at the Marine Corps Logistics Operations Group.

The Marine Corps depot-level maintenance establishment has several recurring issues preventing it from achieving its maximum potential in terms of maintenance production, throughput, and repair cycle-time. However, one depot-level maintenance process was remodeled in 2018 using simulation tools and methods on one particularly problematic vehicle; the light armored vehicle (LAV). This Marine Corps Logistics Command (LOGCOM) sponsored effort spent a substantial amount of time analyzing the areas causing bottlenecks to provide mitigation for this process. In doing so, LOGCOM created a working, living tool that could be repurposed to analyze other vehicles in their system.[2]

DES is defined as such because of the way time is advanced in the model.[3] As opposed to time-step simulation, in which time is advanced in regular increments, a DES model advances time based on the appropriate events scheduled in a network. The key difference between the two is time-step will only show a trend or change in state across time; consequently, individual events themselves can be missed in a time-step simulation. This concern is not present in the DES model because all events are scheduled and removed from the event list, therefore, advancing time between scheduled events according to how long given events must take.[4] The next three figures will provide pictorial representations of the two models being discussed. (e.g., Figure 1 depicts the discrete-event algorithm of how events are added and removed from the event list. Figure 2 depicts the state transitions in a continuous/time-step simulation. Figure 3 depicts the state transitions in a DES model.)

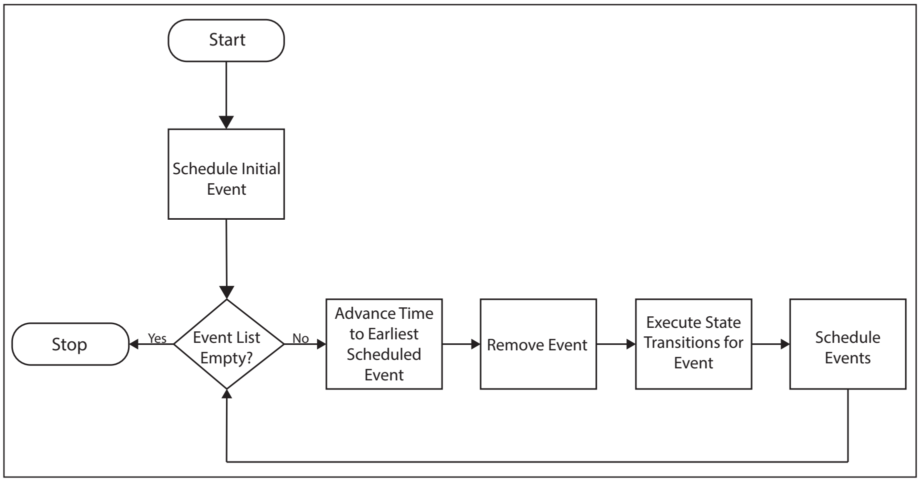

Figure 1. DES next event selection algorithm. ***(Image from Buss.)***

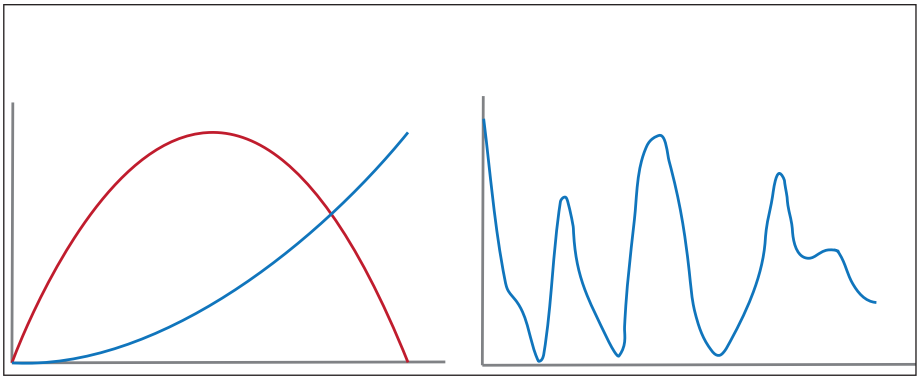

Figure 2. Continuous/time-step simulation state transitions. *(Image from Buss.)*

In a DES model, events are the main triggers, and a single server example is used to explain the concept of DES events.[5] Examples of a single server system are a person arriving in line to be seen by a bank teller or a customer waiting to speak to a service representative on a company's technical support phone line. An "arrival" event is activated to represent the patrons being added to the server's queue. If the server is available to begin service with the person or entity, then a "start service" event takes place. At this point, system state information is captured (e.g., availability of servers/resources and delay-in-queue time). The system will then advance time to represent completion of the stochastically determined service time (i.e., the "end service") event takes place and system state information is captured again (e.g., such as time in system, server/resource availability, etc.). The arrival and service times of a given station are parametric inputs. A random number generator is applied with a probabilistic distribution of the system's data in order to realistically map the inflow and outflow of items within a particular system. In the LOGCOM example, this simple server example is represented by a vehicle being accepted into a queue for its limited technical inspection (LTI) (arrival event), LTI performed (start service event), and leaving that station after the LTI is complete (end service event) to begin its next maintenance step.[6] Figure 4 depicts the behavior of a single server that accepts an entity into its queue and completes service upon specified conditions.

Behavior of any particular step in the maintenance cycle is modeled by incorporating the proper logical flow of how an item's maintenance is expected to take place; in many cases, a simple arrival, begin service, and end service may suffice. For other cases, there may be a need to incorporate delays for quality control failure, spot corrections, or delays where rework is required at previous stations. Component assembly and reassembly may also be represented successfully by creating new entities in the system, where major components of the vehicle are taken off and undergo their own maintenance cycle (e.g., powertrain, suspension, or communications suite).[7]

Once behavior and types of servers are successfully created, the service stations are connected with code in a way that ensures events at any one service station are triggering appropriate events at follow-on stations. Once the system

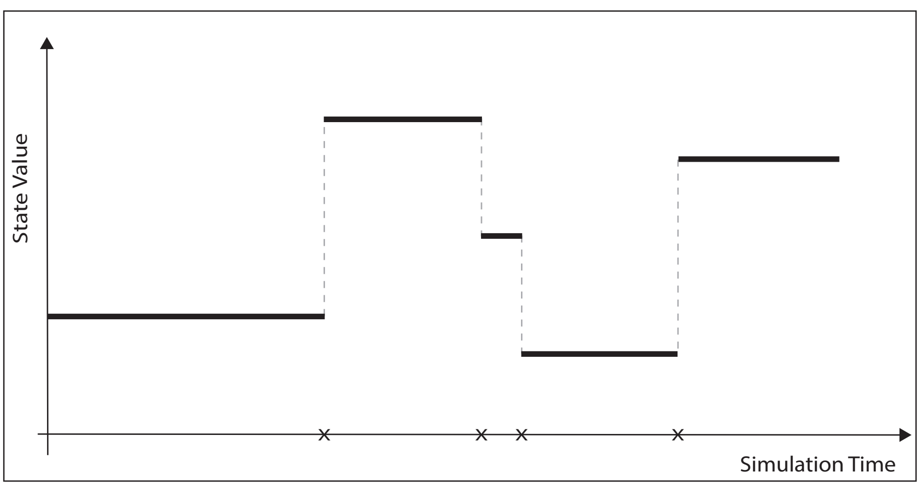

Figure 3. DES state transitions. *(Image from Buss.)*

LAV Entity-Server Class

Parameters

{ts}: set of service times

k: total number of servers

State Variables

s: number of available servers

queue: first in first out container of entities

D: delay in queue

W: time in system

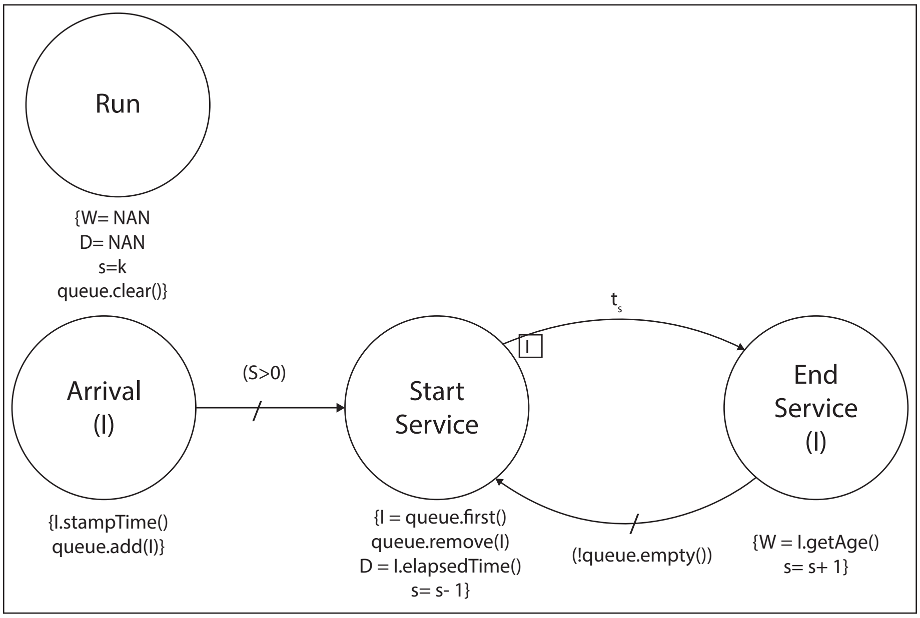

Figure 4. Single server behavior graphic representation. *(Image provided by author.)*

is successfully connected, we can gather statistics and begin data farming to see how the system performs when certain policy decisions are put into effect.[8]

Testing the model consists of running the system with the desired set of inputs. Any given run consisted of a thousand independent replications, with each replication represented five years' time in the maintenance system. The high volume of replications is used to gain confidence in the system and what long-term performance can be expected given the parametric inputs. The LAV study used two primary analysis phases when testing the model. The first tested the throughput of the system as resources (such as employees or maintenance bays) were added to problematic service stations (i.e., where bottlenecks were occurring). Between those runs, resources were incrementally added at the bottlenecks to increase throughput. This incremental process was conducted recursively until all stations were within a prescribed tolerance level. The second phase of analysis tested the varying resource levels, at the problematic stations, during different runs to see how they behaved under different conditions. Varying the conditions determined which stations provided the biggest return on the system as resources were invested into the system.[9] Figure 5 depicts the performance of the system as resources were added to bottleneck stations. Figure 6 demonstrates how the highest payoff servers were statistically identified and explains which resource expansion provided the greatest effect on the maintenance system.

The LOGCOM study found that servers 16 (welding) and 113F (driving differential repair/assembly) had statistically significant impacts on the overall depot-level maintenance cycle time of the LAV. The astounding results proved that DES methods can be effective in solving logistics problems within the Marine Corps. Tying the demonstrated impact of DES, in this particular study, to the greater problems identified in the Marine Corps supply chain system and logistics processes could reap significant rewards for the Service. There are two problem areas that come readily to mind. First, a study on how repair parts are distributed to their end destinations is primed for this level of analysis. The second issue is an analysis on warehousing and maintenance transaction devices.

Currently, the Marine Corps repair part distribution is generally centralized and comes from one of two places: the supporting supply management unit or a Defense Logistics Agency site. Assuming the repair parts are not backlogged (which happens routinely), the parts are shipped individually to the unit, often taking two weeks or more. An alternative to the current process could be establishing a military Autozone-type facility (i.e., where you could physically go and purchase the repair part the same day) at every installation in the Marine Corps. This will allow units to identify the repair parts needed and make an acquisition with the unit's purchase card that very same day. Long shipping times in the maintenance process will be a thing of the past and unit readiness across the Marine Corps will improve. Unlike the current system, where erroneous requisitions become nearly impossible to return and get a refund, a unit could simply take the part back to the shop on base and receive an instanta-

Run	Average Time-in-System	95% Confidence Interval	Average repairs	Employees added	% Cycle-time reduction relative to baseline
Baseline	2966.49	(2940.23, 2992.73)	78.49	-	-
1st Improvement	1630.96	(1611.34, 1650.58)	120.75	10	45.02%
2nd Improvement	1201.52	(1197.10, 1205.94)	131.89	14	59.50%
3rd Improvement	1142.15	(1140.32, 1143.98)	133.32	4	61.50%
4th Improvement	1124.21	(1122.86, 1125.57)	133.43	6	62.10%
5th Improvement	1119.54	(1118.27, 1120.80)	133.68	4	62.26%

Figure 5. Incremental resource capacity expansion and bottleneck mitigation. *(Image provided by author.)*

Source	LogWorth	PValue
16	5.308	0.00000
113F	1.955	0.01108
1134	0.763	0.17267
40	.494	0.32094
1135	0.386	0.41160
34	0.366	0.43074
113C	0.326	0.47154
1138	0.273	0.53395
11312	0.213	0.61191
assemble	0.204	0.62489
14	0.128	0.74416
17	0.088	0.81601
1131	0.072	0.84723
1133	0.041	0.91053
11313	0.022	0.95086
113E	0.016	0.96378

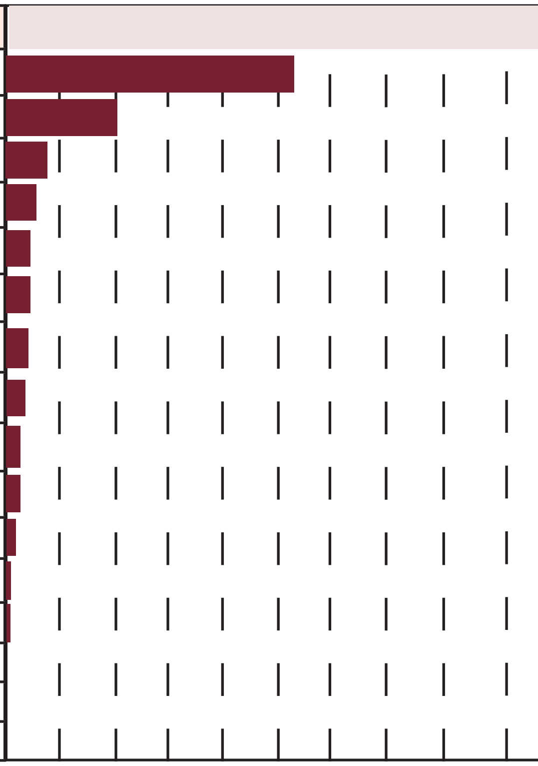

Figure 6. Order of precedence demonstrating which problematic servers had the greatest statistically impact on the overall maintenance cycle time in the system (i.e., from most significant to least significant). *(Image provided by author.)*

neous refund to their operations and maintenance account. Additionally, the stock levels at each installation's shop will be based on previous demand and tailored to the types of repairs that are more likely to occur. The humid coastline of Camp Lejeune will necessitate the need for more corrosion control items than the dry climate of Twentynine Palms. Twentynine Palms, because of its rocky terrain, will require more axle components such as tie rod ends and ball joint boots than elsewhere in the Marine Corps. A DES study could compare the performance of the current system with that of the theoretical system and weigh the benefits of improved readiness and maintenance cycle time across the force. Also, it streamlines the startup costs of establishing the infrastructure and transaction network. DES not only affords the opportunity to explore the short-term effects, but also how the various system adjustments might be expected to affect repair cycle time and unit readiness over the span of years and decades.

In the realm of supply chain sluggishness, the Marine Corps is lagging in terms of warehousing and inventory transactions. Currently, Marines must navigate the user-hostile interface of Global Combat Support System–Marine Corps (GCSS-MC) to locate the appropriate service request and manually input that an inventory transaction has taken place. This could be the warehouse Marine receiving the item from a supply system, an operator from a company/battery applying newly received Stock List 3 to an end item, a Layettes Marine applying a part from his warehouse account to his maintenance inventory, or the mechanic applying a repair part to a vehicle in maintenance. These transactions can take several minutes each if the system is not experiencing a lag or outage. With the technology of today, there is no reason for these transactions to last several minutes per manual entry. We need to leverage both barcode and radio frequency identification technologies to become more efficient. The Service goal must be to utilize these technologies for a nearly instantaneous inventory transaction at any step in the request lifecycle of GCSS-MC. The cost is the time we waste dedicating Marines to continuously complete GCSS-MC transactions, other tasks that are not being fulfilled, and generational loss of overarching tradecraft. A DES study provides a method for insight into what an investment will provide, type of efficiency that could be achieved, and what the American people expect from their Marine Corps.

A DES study is an incredible benefit to the total force and individual warfighters alike and will require a minimal effort to complete. With a team of six dedicated personnel and funding for research/travel costs, a study of this magnitude could be completed typically within six to nine months. Being the center for excellence in Marine Corps logistics operations, MCLOG will be the ideal candidate to spearhead such studies. Along with the various training exercises and courses MCLOG provides, they also maintain innovation as part of their charter. MCLOG will also have the unique opportunity to incorporate their research findings into the greater communities of logistics, supply, maintenance, as well as the logistics education continuum.

MCLOG will also have the unique opportunity to incorporate their research findings into the greater communities of logistics education continuum.

The DES results will provide key leadership a cost-benefit analysis to any of the numerous systems and processes inherent in the Marine Corps. However, there are current shortfalls that limit the ability to begin analyzing and solving these problems. With the burden

MCLOG currently bears in providing collective and individual training to the logisticians throughout the total force, there is little capacity to support such projects, impactful as they may be for the enterprise. MCLOG will need to be resourced with additional personnel with expertise in statistics, research, and experimental design to make this potential analytic capability a reality. Regardless of how the Marine Corps may implement these analytic ideas, thus far, the scope of the analytic activity is focused on existing requirements within the operational or strategic level. Currently, there is no effort to seek out broad, new, and logistics specific problems at the tactical level to then conduct follow-on analysis and implement steps necessary to improve the process.

While simulated training environments are important to the Marine Corps, we have only begun to scratch the surface of its potential to improve both the total force and the individual warfighter. This article demonstrates the effectiveness of DES in decision making and the numerous ways in which a DES will solve major problems in the Marine Corps logistics network. The potential to leverage DES, and other types of simulation to innovate and solve problems, should begin expanding our methods of how we address problems within the Marine Corps.

Notes

1. Defense Modeling and Simulation Coordination Office, "Responsibilities & Governance," *DMSCO,* (Online: 2017), available at https://www.msco.mil.

2. Capt Michael J. Blankenbeker, "USMC Depot-Level Maintenance of the Light Armored Vehicle (LAV): A Discrete-Event Simulation Analysis," (thesis, Monterey, CA: Naval Postgraduate School, 2018).

3. Arnold Buss, *Discrete-Event Simulation (DES) Modeling*, (Monterey, CA: Naval Postgraduate School, 2017).

4. Ibid.

5. Ibid.

6. "USMC Depot-Level Maintenance of the Light Armored Vehicle (LAV): A Discrete-Event Simulation Analysis."

7. Ibid.

8. Ibid.

9. Ibid.

US MC