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A COMPARISON OF TIME AND CONDITION BASED REPORTING POLICIES IN FUEL SUPPLY REPORTING

A Thesis in
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by
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ABSTRACT

Maintaining an adequate fuel supply is absolutely critical for success in any military operation. At the same time, it is not desirable to keep unnecessarily large stockpiles of fuel because it limits the maneuverability of the unit and presents a valuable target for an enemy to attack. It is possible to maintain lower inventories while keeping a low probability of a stock out by reducing the Bullwhip Effect. This can be accomplished by sending fuel level reports from vehicles and fuel storage containers directly up the supply chain. Because military communications networks have limited bandwidth available, the number of reports being sent needs to be kept as small as possible. The goal of this study is to identify reporting policies that both provide an accurate picture of fuel levels up the supply chain and keep the number of reports sent as low as possible. Discrete event simulation models are used to examine a range of time based (ex. report sent every 15 minutes) and condition based (ex. report sent after 10% of the fuel capacity has been used) reporting policies. The results show that condition based reporting policies outperform time based reporting policies by a small margin in vehicles. With fuel storage containers, the condition based reporting policies were far superior.
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Chapter 1: Introduction

Maintaining an adequate fuel supply is absolutely critical for success in any military operation. Despite this importance, the United States Armed Forces have not, until recently, had the ability to track fuel supplies in near-real-time. Currently, the fuel levels in major fuel distribution systems are collected and compiled in the form of daily reports. This leads to a significant gap between the time the fuel is actually used and the time the information is presented to a logistics decision maker (Chiarotti, 2007). Additionally, the fuel that is in vehicles and small distribution systems is not tracked at all, leaving the decision maker with even greater uncertainty.

It is now possible to track fuel levels with much better accuracy and timeliness. New vehicles are already equipped with health monitoring systems that, in addition to many other things, keep track of the vehicle's fuel level (Needham & Snyder, 2009). This information can be sent wirelessly and collected in central databases, making this previously untracked data instantly available to commanders. Sensors and wireless transmitters can also be added to smaller fuel distribution systems to provide the same benefit.

This added information is of great value to decision makers. Logisticians can plan resupplies based on the true fuel levels and usage rates rather than time delayed reports that didn't even attempt to track a sizable portion of the fuel available. Tactical commanders gain a capability that they did not previously have at all—the ability to monitor the fuel levels of units and vehicles on the battlefield. If a patrol needs to be rerouted, the commander can verify that the vehicles have sufficient fuel to make it to the new destination. If a tank is consuming fuel more quickly than anticipated and may not be able to reach its destination, the commander can be notified far in advance and adjust plans accordingly.
Although these advances provide much better information, the information will never be perfect and it is not free. Moving vehicles consume fuel continuously, but only send periodic updates to the databases. Between updates, there will be a discrepancy between the true fuel level and the value stored in the database. The more frequently the vehicles send updates, the more accurate the databases will be. However, bandwidth on military communications systems is a valuable commodity and some sensors rely on batteries. So updates have a cost in terms of bandwidth usage and battery life. Additionally, there is a computational processing cost associated with updating the central databases which may track thousands of vehicles.

The goal of this project is to examine the relationship between bandwidth used and information accuracy. Discrete event simulation will be used to model two military scenarios. The scenarios will be run with either time based or condition based reporting while accuracy and bandwidth usage are measured.

In Chapter 2, we will explore the Bullwhip Effect and how it negatively affects supply chains. We will also look at how Vendor Managed Inventory can help reduce the Bullwhip Effect. Then, we will examine studies from other fields that have attempted to reduce reporting volume while maintaining accuracy. Chapter 3 describes two simulation models that will be used to study both error and reporting volume while experimenting with different reporting policies. The results of these experiments will be described in Chapter 4. Finally, Chapter 5 will draw conclusions from these results and provide recommendations for future research.
Chapter 2: Literature Review

2.1 Introduction

This chapter first discusses what the Bullwhip Effect is, how it can negatively affect supply chains, and one means of mitigating it: information sharing. Next, Section 2.3 examines how military organizations are attempting to increase their effectiveness with Sense and Respond Logistics (S&RL) by reducing inventory but still ensuring that sufficient supplies are available. Then, Section 2.4 will look at a business parallel to S&RL: Vendor Managed Inventory (VMI). If VMI can reduce the Bullwhip Effect, an S&RL system could provide similar benefits in the field of military logistics. Finally, although information sharing reduces the Bullwhip Effect and improves supply chain performance, military communications networks are limited. So, we must also look at ways to reduce reporting volume. Sections 2.5 and 2.6 will look at studies from other fields that have attempted to minimize reporting while maintaining an acceptable level of error (the disparity between the current inventory and the last reported inventory).

2.2 The Bullwhip Effect

For most business, demand is not a stable quantity. In order to compensate for this uncertainty in demand, businesses try to estimate what the demand will be. But even with forecasting, there will be a discrepancy between the expected and true demand for a product. Because of this, businesses carry a “safety stock,” additional inventory to act as a buffer between the actual and forecasted demand. As one moves up the supply chain, the demand oscillation magnifies. Larger and larger safety stocks are required at each level to mitigate the effect of this increased variability. This is known as the Bullwhip (or Forrester) Effect and is a well-established phenomenon in supply chains. (The name comes from the demand oscillation curve, which
resembles a whip being cracked.) The effect is not the result of poor or panicked decision making, but rational decision making within the supply chain's structure (Lee, Padmanabhan, & Whang, 1997).

One of the causes of the Bullwhip Effect is the time delay in demand information (Forrester, 1961). Although the retailer may see immediately that demand has sharply risen, the supplier will not realize this until the retailer places a new order, which may take days if they have sufficient inventory on hand. Several studies have shown that information sharing or centralizing demand information can reduce the Bullwhip Effect and improve supply chain performance (Chen, 1998) (Lin, Huang, & Lin, 2002) (Chen et al., 2000).

2.3 Military Logistics

Just like businesses, military organizations must deal with demand uncertainty and the Bullwhip Effect. In fact, it is even more difficult for the military to handle demand uncertainty due to the extremely high cost (or penalty) associated with running out of critical items during combat operations. In the past, military logisticians created and relied upon large stockpiles of supplies to meet the requirements of the battlefield. These “iron mountains” ensured that the needs of the supported units were met despite the uncertainties of the situation (Griffin, 2008). This approach, however, is not well suited for modern, sustained combat operations where the threats are often sudden and unpredictable. “Iron mountains” limit flexibility and present a valuable target to the enemy. Military organizations have found it increasingly difficult to use this traditional approach on the modern battlefield (Castano-Pardo, Lin, & Williams, 2006). On the other end of the spectrum, a Just-In-Time or Lean approach, although very efficient, is not suitable for military operations because it is more susceptible to supply shortfalls in a highly stochastic environment (Office of Force Transformation, U.S. Department of Defense, 2003).
Following the lead of business leaders like Wal-Mart, Amazon, and Dell, military leaders are modifying their supply chains for transparency and adaptability (Perera, 2007). Specifically, the Department of Defense is moving toward a sense and respond system. A Sense and Respond Logistics (S&RL) system is both predictive and responsive. Unit needs are projected while supply levels and usage rates are monitored in near real-time. S&RL provides the following benefits: 1) reduction in demand uncertainty, 2) reduction of the Bullwhip effect via information sharing, and 3) ability to respond in a timely manner if actual usage deviates significantly from projections. This approach will allow the military to ensure that units are adequately supplied without relying on “iron mountains” or over-supplying.

Of particular interest is the supply of fuel, an absolutely critical item in any military operation. One recent study has shown that far more fuel was delivered than was required in typical scenarios conducted during Operation Iraqi Freedom II (Chiarotti, 2007). Several types of military vehicles and fuel distribution systems are already equipped to monitor fuel levels as well as other vehicle health information. This data can be wirelessly sent to central databases and made instantly available to decision makers at all levels of the supply chain, reducing the Bullwhip Effect. Effective use of this information by logisticians will allow a reduction in the superfluous supply of fuel, without putting units at a greater risk of a shortage. This information will also allow tactical commanders to make better battlefield decisions by providing them with a more complete picture of their units' capabilities.

2.4 Vendor Managed Inventory

One possible business parallel to this S&RL system could be a Vendor Managed Inventory (VMI) system. In a VMI system, inventory data (and, therefore, demand information) is automatically sent from a retailer to a supplier. The supplier is responsible for determining when to resupply the retailer. In the military S&RL system, the demand is experienced at the
vehicle, but the information can be automatically and instantly sent to logisticians or logistical
software at multiple levels of the supply chain to make resupply decisions. So, in both VMI and
this S&RL system, demand information is sent directly to the supplier in close to real time rather
than waiting for the retailer or military unit to request additional supply. Studies have shown that
VMI systems do indeed reduce the Bullwhip Effect (Disney & Towill, 2003a) (Disney & Towill,
2003b), increase overall supply chain performance (Ryu, 2006), and decrease costs across the
supply chain (Rabah & Mahmassani, 2002).

A few studies have examined the effect of error in VMI systems. These studies have
shown that a reduction in information accuracy can have a negative impact on automated
inventory systems (Kang & Gershwin, 2005) (Sahin & Dallery, 2009). However, these studies
were concerned with error due to theft, misplaced inventory, incorrect product identification, etc.,
not errors due to the frequency at which reports are sent. So while they show that error can have a
negative impact on VMI systems, they don't examine the relationship of interest—the trade-off
between accuracy and bandwidth.

Unfortunately, little work has been done to determine what effect varying reporting
policy has on the system. The previously cited studies simply assume instantaneous or daily
information reporting. This is most likely because there is little to no additional cost to sending
out more reports than are necessary, unlike the military systems where bandwidth and battery
power need to be conserved.

VMI systems are the best business analogy to the military S&RL systems. Research in
this arena demonstrates that timely information sharing can improve supply chain performance
and that errors in this information can degrade supply chain performance. To lay the groundwork
for this particular study, however, other fields will have to be examined.
2.5 Vehicle Location Tracking

Systems that track the locations of moving vehicles face the same dilemma as the fuel supply monitoring that this study addresses. There is a great desire to have a central database that accurately tracks status but there is inherent error that can be reduced through more frequent updates (Jensen & Saltenis, 2002). This data can be used by companies to monitor their trucking fleets. It can be used by a taxi service to determine which taxi should be sent to pick up a customer. It can be used to send information back to the vehicles to support location based applications such as a list of nearby businesses or a new route to avoid a traffic jam. Perhaps someday it can be used to track all vehicles on the road to provide better traffic management via traffic signals, etc. As with fuel data, having accurate position information would be of great value to military commanders making battlefield decisions.

Just as with our fuel tracking issue, vehicle location tracking requires frequent updates for accuracy, but has an associated cost in terms of either bandwidth or dollars paid to a service provider (Wolfson et al., 1998). The remainder of this section will discuss studies that have examined this relationship and attempted to find better reporting policies that increase accuracy and decrease bandwidth consumption.

The traditional approaches used in most commercial transportation systems are to send periodic updates based on time (e.g. send an update every 10 minutes) or distance (e.g. send an update every mile traveled). The advantage of the distance based updates is that they provide a known bound on the uncertainty (Wolfson & Yin, 2003). The vehicle must be within a circle centered on the last reported position with a radius equal to the reporting threshold.

Wolfson and Yin (2003) compared this distance based reporting to what they call a deviation policy. In this policy, it is assumed that the vehicle will continue moving down the same street at the same velocity. So instead of relying on the last position update, a current
position is predicted. The vehicle will only send a report when the actual position differs from the predicted position by some distance threshold. Wolfson and Yin found that the distance policy required 43% more updates than the deviation policy, while both had the same bound on uncertainty.

Wolfson et al. (1998) also examined the benefits of predicting future position in reducing the number of updates. Instead of assuming that the vehicle continues on the same street, this study assumes that the entire route of the vehicle is known. Simulations showed that this approach can reduce the number of updates by 85% over the traditional distance based policy while maintaining the same bounds on uncertainty.

Tiesyte & Jensen (2008) examined a slightly different, but related problem. This study was interested in tracking vehicles on known, scheduled routes such as buses. The data needed wasn't the exact position of the vehicle, but the expected time at the next stop. Again, there is a trade-off between error and bandwidth. In the traditional approach, the vehicles send updates every time they reach a stopping point. That information is used to estimate the arrival time at the next stop. A new threshold based reporting policy was developed where updates are only sent if the vehicle is going to arrive at the next stop later than the expected time. (No update is sent if the vehicle is too early, it waits at the stop in that case.) The investigators used real bus data to conduct the analysis. This study demonstrated that the number of updates required can be significantly reduced while maintaining accuracy with this new policy.

2.6 Other Related Studies

Studies that relate accuracy to update frequency are not limited to vehicle tracking. Gupta, Chuah, & Mohapatra (2008) examine the overhead vs. accuracy trade-off in the monitoring of wireless mesh networks. Information such as signal quality or packet loss is monitored and the data is used to improve quality of service by altering the routing algorithms or avoiding nodes
with poor signal. These networks are powered by batteries, so sending superfluous data can reduce the lifetime of the system. The extra traffic can also degrade the performance of the system. The researchers used simulation to analyze the impact of various reporting policies. They looked at the impact of altering the reporting frequency of time based policies as well as the performance of threshold based policies. They found that the time based policy can result in a substantial degradation of the system's performance. The threshold based policy performed much better and was able to reduce overhead while maintaining an acceptable level of accuracy.

In a very different area of study, Leung & Marion (1999) examine the effect of sampling interval (distance) on accuracy in assessing the condition of backcountry trails in the Great Smoky Mountains National Park. Trails must be inspected from time to time to ensure that they haven't been significantly impacted by problems such as erosion or muddiness. Instead of inspecting the entire trail (which would have a great cost in terms of time), various points are sampled to estimate the condition of the entire trail. The investigators took real data from extensively inspected trails and used different sampling intervals to look at points on these trails, then compared the estimated impact with the true impact. They found that as the sampling intervals increased, the accuracy of the sampled data decreased. They then proposed an appropriate interval based on their results that reduced the number of sampling points needed but still provided an acceptable accuracy.

Lam, Leong, and Chan (2004) showed that updates could be reduced for vehicles traveling in groups. Instead of all vehicles sending reports, only an assigned vehicle sends updates for all vehicles in the group. This method led to significant reductions in the number of updates required in their simulation based experiment.
2.7 Summary

The Bullwhip Effect negatively affects supply chains and requires businesses to carry more inventory to prevent stock outs. One means of mitigating the Bullwhip Effect is sharing demand information. VMI systems utilize immediate information sharing to suppliers and have been shown to reduce the bullwhip effect. A military S&RL system would work similarly to a VMI system by transmitting demand data directly to suppliers, so it should provide similar benefits.

Simply sharing all demand information immediately is not possible in the military because communication bandwidth is limited. Many studies have been conducted that attempt to examine the relationship between a reporting policy (and, hence, bandwidth or overhead) and the accuracy of the reported data. While high accuracy is desired, there is a cost associated with the reporting policy. A common and effective approach to this genre of problem is to create a simulation that allows the comparison of several different reporting policies. The results of these simulations can be used to study the relationship. A cost function or a trade space analysis can then be conducted to determine the best policy for a specific situation.
Chapter 3: Methodology

3.1 Objective

In military operations, accurate information on fuel inventory is extremely valuable. Fuel sensors and communications technology allow this information to be collected in near real-time. However, communications bandwidth is a limited commodity, so sending constant updates is not a viable option. The objective of this study is to identify fuel reporting policies that both provide accurate information on fuel inventory and keep the total bandwidth usage low.

The study will use discrete event simulation models to examine a range of time based (ex. report sent every 15 minutes) and condition based (ex. report sent after 10% of the fuel capacity has been used) reporting policies. The study will examine reporting policies for both vehicles and fuel storage containers.

There are two simulation scenarios being examined – unscripted and scripted. In the unscripted scenario, the vehicle usage is stochastic. Vehicles are sent on patrols or used for short durations on base at random time intervals. In the scripted scenario, the use of every vehicle is deterministic and follows the schedule in Appendix D.

3.2 Unscripted Scenario

The unscripted scenario being modeled is that of a United States Marine Corps Battalion Landing Team (BLT) operating out of a base with a fixed position. The BLT will be conducting patrols of varying distances and average speeds around their base. Additionally, there will be some vehicle use of short duration on base. The BLT possesses a variety of vehicle types that have different fuel capacities and consumption rates (Appendix E). Some of the vehicles carry
fuel containers called SIXCONs that provide fuel to other vehicles as required (these vehicles will be referred to as fuel suppliers).

A patrol consists of several vehicles that are randomly selected from the BLT to drive for some speed and distance on a specific road surface type. The patrols are sent out randomly with the time between patrols based on an exponential distribution. A patrol will consist of 4-10 HMMWVs (45% probability), 4-10 LAVs (25% probability), 2-6 HMMWVs plus 2-6 MTVRs (10% probability), or 4-6 AAVs plus 0-4 M1A1s (20% probability). The road surface, speed, and distance are also randomly assigned. As the vehicles drive, they consume fuel constantly, but only send reports of their fuel level periodically when they reach some time or condition criteria. Fuel suppliers do not go on patrols in this scenario. On base vehicle use is basically the same except that vehicles are sent out individually, rather than as a group, and only one type of vehicle is used—HMMWV.

Vehicles always fill their fuel tank to full capacity before going on a patrol. When vehicles complete a patrol or a movement on base, they refuel if they have less than 75% of their capacity. The volume is deducted from one of the fuel supplying SIXCONs and added to the vehicle's tank.

3.3 Scripted Scenario

The scripted scenario represents a BLT conducting a movement to an objective (where all of the vehicles are moving from one location to another) for one day then conducting patrols from a fixed position for nine days. Unlike the unscripted scenario, where the simulation randomly determines vehicle activity, all vehicle activity and refueling times are deterministically set in the models.
3.4 Assumptions

1) In addition to sending a fuel report when a time or condition criteria is met, vehicles always send a startup and shutdown report.

2) Fuel consumed while traveling from parking areas to fuel stations, from parking areas to patrol launch points, and from fuel stations to patrol launch points is considered negligible. No fuel is consumed in the model and the travel time is zero.

3) Fuel tank refills (vehicle and SIXCON) occur instantaneously.

4) The only vehicles used on base are HMMWVs.

5) The fuel containers (SIXCONs) instantaneously refill once their fuel level gets below an arbitrarily set number. In this model, they refill once they are below 20% of their capacity.

6) Measurement error is not modeled. The vehicles and SIXCONs always send perfectly accurate reports.

7) If a fuel supplier has multiple SIXCONs, any fuel distributed comes from each SIXCON in equal portions.

8) The sensor on a vehicle's fuel tank uses vehicle power. The fuel status can be checked near-continuously. When reporting is condition based, the vehicles will send a fuel report at the instant they reach the reporting condition.

9) The sensor on a SIXCON is powered by external batteries. These sensors will not check the tank near-continuously in order to extend battery life. With time based reporting, the fuel level will be checked whenever a report needs to be sent. With condition based reporting, the fuel level will be checked every 15 minutes. If the reporting threshold has been exceeded, a fuel report will be sent. So, in this case, reports are not sent exactly when the reporting condition is met.

10) Specific assumptions for the Unscripted Scenario:
a) The vehicles carrying fuel containers do not go on patrols.

b) Patrols and on base vehicle use occur exclusively on one type of road surface: paved, hard, or soft. Fuel consumption changes greatly depending on the road surface. If the road surface type varied randomly during a patrol, there is a chance that the soft surface would occur frequently and result in a large amount of fuel being consumed. This could lead to vehicles running out of fuel while on patrol. An alternative would be to send patrols on predefined “routes” that have predefined changes in road surface type. This approach was deemed to be too detailed for a preliminary study. Instead, the road type is randomly chosen first and remains unchanged throughout the patrol. The patrol’s length and speed will be chosen based on the road surface type. i.e. patrols on paved roads will be faster and longer than those on soft surfaces.

c) When a patrol is being created, if the quantity of vehicles required is greater than the number available, the patrol just goes with the available vehicles.

d) There are different rates for patrols and on base uses at night. In this model, the night rate is 5% of the day rate. Day is defined as 5am – 8pm.

3.5 Unscripted Scenario Model Overview

The vehicles are represented as loads in the AutoMod Model. Attributes store the information about the vehicle type, fuel capacity, true fuel level, reported fuel level, etc. The vehicles are created during model initialization. Once created, the fuel supplying vehicle loads are sent to a process where they send reports as time or condition criteria are reached. (The fuel supplying vehicles do not actually move in this scenario.) The remaining vehicles are sent to an idle vehicle order list where they wait to be sent on patrols or used on base.

A load is used to schedule the patrols. It is in a loop that repeats for the duration of the simulation (Figure 3-1). First, it waits some time randomly drawn from an exponential
distribution. If it is daytime (5am – 8pm), a patrol will be sent. If it is nighttime, a patrol will be
sent with a probability of 0.05. If a patrol is being sent, it randomly picks a patrol road type,
speed, and distance. Then, the number and type of vehicles for the patrol is determined. A patrol
will consist of 4-10 HMMWVs (45% probability), 4-10 LAVs (25% probability), 2-6 HMMWVs
plus 2-6 MTVRs (10% probability), or 4-6 AAVs plus 0-4 M1A1s (20% probability). The exact
number of vehicles is chosen from a uniform distribution from ranges listed. The specified
number of each vehicle type is ordered from the idle vehicle order list to continue to a patrol
process. Similarly, a load is used to schedule the on base trips by vehicles (Figure 3-2). The
difference is that it only orders one idle vehicle (always a HMMWV) to continue to the on base
use process.

**Patrol Scheduling Loop**

If daytime (5am – 8pm):
Send vehicles on patrol
If nighttime (8pm – 5am):
5% chance of sending vehicles on patrol
95% chance of doing nothing

**Figure 3-1: Unscripted Scenario, Patrol Scheduling Loop**
In the patrol process, each vehicle first sends a startup report (i.e. updates its reported fuel level attribute and increments the counters that keep track of the reports sent). It then refuels if it does not have a full tank (which also means it will send a shutdown report and another startup report). The vehicle enters a loop where it waits until the next report criteria (time or condition-based) is met then sends a report. It remains in this loop for the length of the patrol. The vehicle then refuels (again sending a shutdown and startup report). Finally, the vehicle is parked (sends a final shutdown report). The load is ordered to wait on the idle vehicles order list. The on base use process is essentially the same as the patrol process. The only difference is in the refueling rules. In this case, the vehicle does not refuel before departing and only refuels at the end of the trip if the tank is less than 75% of its capacity. This vehicle movement process is shown in Figure 3-3.
Another load is responsible for comparing the true and reported fuel levels. It is in a process with an infinite loop where it waits one minute, then checks the reported and true fuel levels for all vehicles and SIXCONs. It calculates the true fuel level, reported fuel level, and error for vehicles and SIXCONs. These values are written to a data file. They can also be tracked through a business graph as the model runs.
The simulation code for the unscripted scenario is found in Appendix A.

3.6  *Scripted Scenario Model Overview*

The scripted scenario model is largely the same as the unscripted model. The one area that is different is the scheduling. There is no patrol or on base use scheduling loop in the scripted scenario. Instead, the vehicle movement times, road types, speeds, and distances are deterministic. These factors are hard coded into the model and follow the schedule in Appendix D.

The vehicle movement itself is handled in the same manner as the unscripted scenario shown in Figure 3-3 as is the comparison between the actual and reported fuel levels.

The simulation code for the scripted scenario is found in Appendix B.
Chapter 4: Results

4.1 Experimentation

4.1.1 Experimental Levels

In order to find policies that keep both error and bandwidth low, the simulation models will vary the time or condition based reporting criteria and record the mean error, max error, and total number of reports sent. In the unscripted scenarios, the patrol rate was also varied to see the effect of vehicle activity levels on the reporting policies. The patrol rate is the average number of patrols sent per hour. \((1 / \text{patrol rate})\) is the mean time between patrols and this value is used as the lambda parameter for the exponential distribution determining the time between patrols (Figure 3-1). A higher patrol rate results in higher overall vehicle activity.

In the time based reporting simulation runs, the vehicles send a report at startup, an addition report at every reporting interval while running, and a shutdown report. The SIXCON reports are sent at every reporting interval throughout the simulation. In the condition based reporting simulation runs, the vehicles send a startup report, an addition report every time the fuel level changes by the reporting criteria (given in terms of % tank capacity), and a shutdown report. The SIXCON tank level is checked every 15 minutes throughout the simulation. When the level is checked, if the volume change has exceeded the reporting criteria (in gallons, SIXCON capacity is 900 gallons) a report is sent.

The experimental levels for the unscripted scenario with time based reporting (297 total runs), the unscripted scenario with condition based reporting (180 total runs), the scripted scenario with time based reporting (99 total runs), and the scripted scenario with condition based reporting (60 total runs) are shown in Table 4-1, Table 4-2, Table 4-3, and Table 4-4, respectively. One run was completed at each possible combination of the experimental levels.
The duration of the simulations for the scripted scenarios was 10 days. For the unscripted scenarios, the simulation runs were 30 days.

### Table 4-1: Unscripted Scenario, Time Based Reporting Experimental Levels

<table>
<thead>
<tr>
<th>Factor</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patrol Rate</td>
<td>.25, ,5, .75 (patrols/hr in daytime)</td>
</tr>
<tr>
<td>SIXCON Report Interval</td>
<td>.25, ,5, 1, 2, 4, 8, 12, 18, 24 (hours)</td>
</tr>
<tr>
<td>Vehicle Report Interval</td>
<td>.25, ,5, .75, 1, 1.5, 2, 2.5, 3, 4, 5, 6 (hours)</td>
</tr>
</tbody>
</table>

### Table 4-2: Unscripted Scenario, Condition Based Reporting Experimental Levels

<table>
<thead>
<tr>
<th>Factor</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patrol Rate</td>
<td>.25, ,5, .75 (patrols/hr in daytime)</td>
</tr>
<tr>
<td>SIXCON Report Criteria</td>
<td>1, 5, 10, 20, 40, 80 (gallons)</td>
</tr>
<tr>
<td>Vehicle Report Criteria</td>
<td>1, 2.5, 5, 10, 15, 20, 25, 30, 40, 50 (% tank capacity)</td>
</tr>
</tbody>
</table>

### Table 4-3: Scripted Scenario, Time Based Reporting Experimental Levels

<table>
<thead>
<tr>
<th>Factor</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIXCON Report Interval</td>
<td>.25, ,5, 1, 2, 4, 8, 12, 18, 24 (hours)</td>
</tr>
<tr>
<td>Vehicle Report Interval</td>
<td>.25, ,5, .75, 1, 1.5, 2, 2.5, 3, 4, 5, 6 (hours)</td>
</tr>
</tbody>
</table>

### Table 4-4: Scripted Scenario, Condition Based Reporting Experimental Levels

<table>
<thead>
<tr>
<th>Factor</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIXCON Report Criteria</td>
<td>1, 5, 10, 20, 40, 80 (gallons)</td>
</tr>
<tr>
<td>Vehicle Report Criteria</td>
<td>1, 2.5, 5, 10, 15, 20, 25, 30, 40, 50 (% tank capacity)</td>
</tr>
</tbody>
</table>

#### 4.1.2 Error Calculations

The simulation keeps track of the last reported fuel level for every vehicle and SIXCON. Every minute, the true fuel level in the vehicles and SIXCONS is calculated. The percent error is
then calculated as \((\text{true fuel level} - \text{reported fuel level}) / \text{fuel capacity}) \times 100\). As stated in the objective (Section 3.1), one goal is to minimize this error.

There are two types of error that can occur: overestimation and underestimation. In overestimation, the reported fuel levels are higher than the true values. In underestimation, the reported fuel levels are less than the true values. The cost associated with underestimating fuel levels may be (and probably is) quite different than the cost of overestimating.

The only time the vehicles could underestimate is after they refuel and before they send their next report. Since the refueling is considered instantaneous and the vehicle sends a startup report immediately after fueling, this can't occur in this model. The SIXCONs can underestimate between the time they are refilled and the time they send their next report. It doesn't occur very often and it typically won't be for a long duration of time, but it needs to be handled separately. Simply adding it into the total SIXCON error and total error isn't appropriate because it will actually mask some of the underestimation error. Taking the absolute value and adding it to the other error is inappropriate as well because the costs of the two error types will likely be different. This study will focus on overestimation error and underestimation errors will be dropped. Any SIXCON that is underestimating will simply be ignored when tallying total SIXCON fuel level, total SIXCON reported fuel level, and total SIXCON capacity. If someone were interested in these numbers, they could easily be captured in another study.

4.2 The Effect of Reporting Policy on Error

4.2.1 Time Based Reporting

The results show that as the vehicle reporting interval increases, the error increases. This relationship is visible in both the mean error (Figure 4-1) and maximum error (Figure 4-4 and Figure 4-6). This is a result that we would expect. As more time passes between reports, the
disparity between the true fuel level in the tank and the last reported fuel value grows. In these figures, there are 396 total experimental runs depicted, with 36 runs at each of the reporting intervals.

These figures also show that as the vehicle reporting interval increases, the error rises at a slower rate. The vehicles in these scenarios always send both a startup and shutdown report. Error is reduced when vehicles send reports. So once the reporting interval is greater than the patrol length, it doesn’t matter how large the reporting interval is. For example, if a patrol is just under 3 hours in duration, whether the vehicle reporting interval is 3, 4, 5, or 6 hours, the vehicle will only send 2 reports and the error will be identical at all times. The 3 hour reporting interval only reduces error more than the 6 hour reporting interval on patrols that are longer than 3 hours. A 5 hour reporting interval vehicle only sends more messages than a 6 hour reporting interval vehicle on patrols longer than 5 hours, which is only a small percentage of the patrols. This can be seen more clearly in Figure 4-2, Figure 4-3, and Figure 4-5 where a linear regression line has been added using only the data from the first hour (unscripted scenario, where patrols can be as short as 50 minutes) or first two hours (scripted scenario, where the shortest vehicle movement is 2 hours). It is also very clear in Figure 4-6 which shows the maximum error in the scripted scenario. In the scripted scenario, the maximum vehicle error tends to occur on day one when all of the vehicles move for 3 hours. The 3, 4, and 5 hour vehicle reporting intervals all perform identically. The 6 hour vehicle reporting interval has a slightly higher maximum error because it occurs on day 6 when many vehicles are traveling for over 5 hours.

Additionally, these figures demonstrate that higher vehicle activity levels (higher patrol rate) result in increased mean and maximum vehicle error. Patrol rate is the number of patrols sent per hour in the daytime (5am – 8pm). The nighttime rate is 5% of the daytime rate. Therefore, an unscripted scenario simulation with a .25 patrol rate has half as many patrols as a simulation with a .5 patrol rate and only one third of the patrols as a simulation with a .75 patrol rate. The
expected number of patrols per day for the .25, .5, and .75 patrol rates are 3.8625, 7.725, and 11.5875, respectively (patrols per day = patrol rate * 15 hours + patrol rate * 9 hours * .05). The scripted scenario has the highest overall vehicle activity. In addition to patrols, the entire BLT moves on day 1 and again on day 5 or 6. On the other 7 days, an average of 8.57 patrols were sent out per day (Appendix B).
Figure 4-1: Mean Vehicle Error vs. Vehicle Reporting Interval

Figure 4-2: Mean Vehicle Error vs. Vehicle Reporting Interval with Regression
Figure 4-3: Mean Vehicle Error vs. Vehicle Reporting Interval with Regression

Figure 4-4: Maximum Vehicle Error vs. Vehicle Reporting Interval, Unscripted Scenario
Figure 4-5: Maximum Vehicle Error vs. Vehicle Reporting Interval with Regression

Figure 4-6: Maximum Vehicle Error vs. Vehicle Reporting Interval, Scripted Scenario
We can also see from Figure 4-1, Figure 4-2, Figure 4-4, and Figure 4-5 that the error variance (both mean and max) increases as the vehicle reporting interval increases in the unscripted scenarios. Table 4-5 illustrates that the mean and max error variance with a vehicle reporting interval of 6 hours is orders of magnitude greater than the variance with a vehicle reporting interval of .25 hours. This is true with all patrol rates. The same effect is not seen in the scripted scenario because the vehicle movements are deterministic and the errors will be identical across simulation runs.

Table 4-5: Mean and Maximum Vehicle Error Variance, Time Based Reporting

<table>
<thead>
<tr>
<th>Patrol Rate (patrols/hr)</th>
<th>Reporting Interval = .25 (hrs), Mean Vehicle Error Variance</th>
<th>Reporting Interval = 6 (hrs), Mean Vehicle Error Variance</th>
<th>Reporting Interval = .25 (hrs), Max Vehicle Error Variance</th>
<th>Reporting Interval = 6 (hrs), Max Vehicle Error Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>.25</td>
<td>0.00001459</td>
<td>0.007729</td>
<td>0.04903</td>
<td>7.584</td>
</tr>
<tr>
<td>.5</td>
<td>0.00004067</td>
<td>0.01956</td>
<td>0.02905</td>
<td>3.478</td>
</tr>
<tr>
<td>.75</td>
<td>0.00004221</td>
<td>0.01468</td>
<td>0.02137</td>
<td>3.724</td>
</tr>
</tbody>
</table>

The results show that the same relationship is present with SIXCONs using time based reporting. As the SIXCON reporting interval increases, both the mean (Figure 4-7) and maximum (Figure 4-8 and Figure 4-9) SIXCON error increases. In these figures, 396 total runs are shown, with 44 runs at each of the SIXCON reporting intervals. Also similar to the vehicles, increased vehicle activity leads to increased mean error. The impact of vehicle activity is a bit less clear when looking at maximum SIXCON error, but increased activity does seem to increase maximum error. The lowest activity level (patrol rate of .25 patrols/hr) tends to have the lowest maximum error at each reporting interval while the highest activity level (patrol rate of .75 patrols/hr) tends to have the highest maximum error at each reporting interval (Figure 4-8). There are a few reporting intervals where the intermediate activity level (patrol rate of .5 patrols/hr) has the
highest maximum error. The maximum error is an instantaneous value that occurs at some point in the simulation. Given the stochasticity of the simulation, it is not unreasonable for this to occur.

Unlike the vehicles, however, the SIXCONs error does not level off with the higher reporting intervals. While the vehicles send startup and shutdown reports in addition to the time based reporting, the SIXCONs have no such supplemental reporting. Without exception, the higher the SIXCON reporting interval, the greater the time between reports will be.

Although the scripted scenario points seem to line up perfectly in Figure 4-7, there is some slight variation in the numbers. Although the vehicle movement is deterministic, there are a couple of sources of variability in the simulation (Appendix C). First, when the vehicles return from movement, they don’t immediately refuel. Each vehicle refills at some randomly assigned time over the following 20 minutes (chosen from a uniform distribution). Since the vehicles are not refueling at identical times across runs, there is some variation in the SIXCON error. This is the cause of the variation in SIXCON error in the time based reporting experiments. This variation is most clearly seen in the 15 minute reporting interval in Figure 4-9. There is an additional source of variation that has an effect only on the condition based reporting experiments. The vehicles randomly select a fuel supplier when they need fuel. This source of variation will be discussed in Section 4.2.2.

One data point that stands out in Figure 4-9 is the maximum SIXCON error when the reporting interval is 12 hours. It is significantly lower than the maximum SIXCON error when the reporting interval is 8 hours and seems to break the pattern of higher reporting intervals leading to higher maximum errors. This point is really just a function of the scenario itself (Appendix D). First, we’ll examine a reporting interval of 8 hours. All of the vehicles are moving on Day 1 and stop to refuel at 0800. Since they don’t refeul instantly, the SIXCONs all send off their reports before any fuel is actually dispensed. The vehicles then move for another 2-4 hours and refuel again. At this point, the SIXCONs are still reporting that they are at 100% of capacity even
though significant volumes of fuel have been dispensed. It isn’t until 1600 that the SIXCONs accurately report their fuel levels. With a reporting interval of 12 hours, on the other hand, the SIXCONs send reports at 1200. This report catches all of the fuel that was dispensed from 0800-0820 and from 1100-1120. Since this occurs before the refuelings at 1200-1220 and 1300-1320, the maximum error accumulated is much lower than that of the 8 hour reporting interval. So, while higher SIXCON reporting intervals typically lead to higher maximum SIXCON errors, that may not be the case in a specific instance.

![Mean SIXCON Error vs. SIXCON Reporting Interval](image)

*Figure 4-7: Mean SIXCON Error vs. SIXCON Reporting Interval*
Figure 4-8: Maximum SIXCON Error vs. SIXCON Reporting Interval

Figure 4-9: Maximum SIXCON Error vs. SIXCON Reporting Interval
Lastly, also similar to the vehicles, the variance in mean and maximum error increase as the reporting interval increases. Table 4-6 demonstrates that the variance at the largest reporting interval (24 hours) is an order of magnitude larger than the variance at the shortest reporting interval (15 minutes) for maximum SIXCON error and several orders of magnitude larger for mean SIXCON error.

<table>
<thead>
<tr>
<th>Patrol Rate (patrols/hr)</th>
<th>Reporting Interval = .25 (hrs), Mean SIXCON Error Variance</th>
<th>Reporting Interval = 24 (hrs), Mean SIXCON Error Variance</th>
<th>Reporting Interval = .25 (hrs), Max SIXCON Error Variance</th>
<th>Reporting Interval = 24 (hrs), Max SIXCON Error Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>.25</td>
<td>.00002152</td>
<td>.04503</td>
<td>4.943</td>
<td>18.06</td>
</tr>
<tr>
<td>.5</td>
<td>.00003845</td>
<td>.1835</td>
<td>6.316</td>
<td>27.70</td>
</tr>
<tr>
<td>.75</td>
<td>.00003029</td>
<td>.1975</td>
<td>3.412</td>
<td>16.40</td>
</tr>
</tbody>
</table>

**4.2.2 Condition Based Reporting**

Similar to the relationship seen in the vehicle time based reporting, increasing the vehicle reporting condition results in an increased mean (Figure 4-10) and maximum (Figure 4-11 and Figure 4-12) vehicle error. We also see the relationship level off with the larger reporting conditions. This occurs for the same reason discussed in the vehicle time based reporting. The vehicles typically run for durations less than 30% of their tank capacity in these scenarios. Since a shutdown report is always sent, increasing the reporting criteria beyond that does not have a great impact on the error. We can again see the impact of vehicle activity on error. Higher levels of vehicle activity (higher patrol rate) increase both the mean and maximum error. In these figures, there are 180 total runs for the unscripted scenario and 60 total runs for the scripted scenario. For each patrol level, vehicle reporting condition combination, there are 6 runs. There are also 6 runs.
for each vehicle reporting condition in the scripted scenario, but they align perfectly due to the deterministic vehicle usage.
Figure 4-11: Maximum Vehicle Error vs. Vehicle Reporting Condition, Unscripted Scenario

Figure 4-12: Maximum Vehicle Error vs. Vehicle Reporting Condition, Scripted Scenario
As with the time based reporting, the mean and maximum error variance increases as reports are sent less frequently (reporting criteria increases). This can be seen in Figure 4-10, Figure 4-11, and Table 4-7. The mean and maximum error with the highest reporting criteria is orders of magnitude larger than those with the smallest reporting criteria.

**Table 4-7: Mean and Maximum Vehicle Error Variance, Condition Based Reporting**

<table>
<thead>
<tr>
<th>Patrol Rate (patrols/hr)</th>
<th>Reporting Criteria = 2.5 (hrs), Mean Vehicle Error Variance</th>
<th>Reporting Criteria = 50 (hrs), Mean Vehicle Error Variance</th>
<th>Reporting Criteria = 2.5 (hrs), Max Vehicle Error Variance</th>
<th>Reporting Criteria = 50 (hrs), Max Vehicle Error Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>.25</td>
<td>.00001017</td>
<td>.004129</td>
<td>.005736</td>
<td>5.125</td>
</tr>
<tr>
<td>.5</td>
<td>.00007769</td>
<td>.007646</td>
<td>.01910</td>
<td>2.594</td>
</tr>
<tr>
<td>.75</td>
<td>.00009135</td>
<td>.005928</td>
<td>.009952</td>
<td>.8291</td>
</tr>
</tbody>
</table>

The results show that the SIXCONs also exhibit an increase in mean (Figure 4-13) error as the reporting condition increases. This is similar to the results for the vehicle condition based reporting. While the vehicle error levels off with the larger reporting criteria, the mean SIXCON error continues to rise across all reporting conditions. Figure 4-13 depicts 240 total runs, 180 unscripted and 60 scripted. There are 10 runs for each patrol rate, SIXCON reporting condition combination in the unscripted scenario. There are also 10 runs for each SIXCON reporting condition in the scripted scenario.

The maximum SIXCON error (Figure 4-14 and Figure 4-15), however, does not have such a clear relationship with the reporting criteria. There may be some increase in the maximum SIXCON error as the SIXCON reporting condition increases in the unscripted scenario (Figure 4-14), it is not nearly as clear as it is in the vehicle condition based reporting. The variation within a reporting condition is large compared to the variation across reporting conditions. With the scripted scenario (Figure 4-15), there doesn’t appear to be any relationship at all between the SIXCON reporting condition and the maximum SIXCON error.
The largest SIXCON errors occur after a large patrol or multiple patrols return and refuel. The SIXCONs do not constantly assess their current fuel level. Instead, the tanks are checked every 15 minutes. If the change in the fuel level exceeds the reporting condition, a report is sent. When these large refueling events occur, they are likely to go beyond any of the reporting conditions that were tested. Therefore, in terms of maximum SIXCON error, the largest reporting conditions tested perform as well or nearly as well as the lowest reporting conditions tested.

As mentioned in Section 4.2.1, there is variability in the scripted scenario for the SIXCONs. One cause of this is the 20 minute interval over which the vehicles refuel when they complete a movement. The other is due to the fact that they randomly select a fuel supplier when they refuel. In the time based reporting simulation runs, the SIXCONs all sent reports at the exact same time. So it didn’t really matter which SIXCON had the error. When aggregated, the result is identical whether the fuel dispensed was evenly spread across the SIXCONs or concentrated on just a few. With conditioned based reporting, however, it makes a difference. If the draw is spread very evenly, all of the SIXCONs will get close to their reporting threshold before any reports are sent. So the maximum possible error in terms of volume is (reporting threshold * number of SIXCONs). If all fuel was drawn from one SIXCON, however, it would hit its reporting threshold repeatedly while the other SIXCONs have zero error. In this case, the maximum possible error in terms of volume is simply the reporting threshold.
Figure 4-13: Mean SIXCON Error vs. SIXCON Reporting Condition

Figure 4-14: Maximum SIXCON Error vs. SIXCON Reporting Condition, Unscripted Scenario
Figure 4-15: Maximum SIXCON Error vs. SIXCON Reporting Condition, Scripted Scenario

As with the vehicle condition based reporting and both the vehicle and SIXCON time based reporting, the mean and maximum error variance increases as the frequency of reports decreases (reporting criteria increases). This is shown in Figure 4-13, Figure 4-14, and Table 4-8. Again, the error variances with the largest reporting criteria are orders of magnitude larger than those with the smallest reporting criteria.

Table 4-8: Mean and Maximum SIXCON Error Variance, Condition Based Reporting

<table>
<thead>
<tr>
<th>Patrol Rate (patrols/hr)</th>
<th>Reporting Criteria = 1 (gallons), Mean SIXCON Error Variance</th>
<th>Reporting Criteria = 1 (gallons), Max SIXCON Error Variance</th>
<th>Reporting Criteria = 80 (gallons), Mean SIXCON Error Variance</th>
<th>Reporting Criteria = 80 (gallons), Max SIXCON Error Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>.25</td>
<td>.000004343</td>
<td>.03985</td>
<td>4.731</td>
<td>4.605</td>
</tr>
<tr>
<td>.5</td>
<td>.00005856</td>
<td>.03701</td>
<td>1.801</td>
<td>1.992</td>
</tr>
<tr>
<td>.75</td>
<td>.00003355</td>
<td>.02816</td>
<td>.9364</td>
<td>4.977</td>
</tr>
</tbody>
</table>
4.3 The Effect of Reporting Policy on Report Volume

4.3.1 Time Based Reporting

As one would expect, the results show that as the reporting interval increases, the mean number of vehicle reports sent per day decreases (Figure 4-16).

Because most patrols are shorter than 3 hours in duration and the vehicles always send shutdown reports, the number of reports sent levels off once the reporting interval is greater than 3 hours. When the patrol is shorter in duration than the vehicle reporting interval, the only reports sent are the startup and shutdown reports.

![Mean Vehicle Reports Sent Per Day vs. Vehicle Reporting Interval](image)

SIXCON reporting volume also decreases as the reporting interval increases (Figure 4-17). In this case, the reporting volume is completely independent of vehicle activity. While the vehicles only send reports while running, the SIXCONs send their reports throughout the scenario. This means that the number of reports sent is a constant based on the SIXCON reporting interval.
4.3.2 Condition Based Reporting

Again, the results match our expectations. As the vehicle reporting condition increases, the mean number of vehicle reports sent per day decreases (Figure 4-18). As we saw with the time based reporting, the effect levels off due to the fact that few patrols are long enough to cause the vehicles to reach the higher reporting conditions.
Figure 4-19 shows that the SIXCONs show a very similar relationship. Because there is no equivalent to the vehicle shutdown messages in the SIXCONs, there is no leveling off in the higher SIXCON reporting conditions.
4.4 The Effect of Reporting Volume on Error

4.4.1 Vehicles

The results show that as the mean number of vehicle reports sent per day increases both the mean (Figure 4-20) and max (Figure 4-21, Figure 4-22, and Figure 4-23) vehicle error decrease. This is no surprise. The more frequently vehicle reports are sent, the smaller the disparity between the reported volume of fuel in the tank and the actual volume of fuel in the tank.

Both the time based reporting and condition based reporting results are shown on these graphs to determine if one is superior in terms of error reduction per report. In terms of mean vehicle error (Figure 4-20), the time and condition based policies appear to perform similarly. For a given vehicle activity level (patrol rate), if a time based policy has the same mean number of vehicle reports sent per day as a condition based policy, they will have an approximately equal
mean vehicle error. Since the blue triangles and red circles more or less overlap in Figure 4-20, they are performing equivalently well.

Figure 4-20: Mean Vehicle Error vs. Mean Vehicle Reports Sent per Day
When it comes to maximum vehicle error, however, condition based reporting outperforms time based reporting in terms of error reduction per report. When the reporting volume is fairly low, condition based reporting does a better job of limiting the maximum error on a per report basis. This can be seen in Figure 4-21. It is more clear if we expand two of these graphs (Figure 4-22 and Figure 4-23). This shows an advantage to using condition based reporting. Maximum vehicle error is reduced without sending more reports.
Figure 4-21: Maximum Vehicle Error vs. Mean Vehicle Reports Sent per Day
Figure 4-22: Maximum Vehicle Error vs. Mean Vehicle Reports Sent per Day, Unscripted Scenario, Patrol Rate = .75

Figure 4-23: Maximum Vehicle Error vs. Mean Vehicle Reports Sent per Day, Scripted Scenario
4.4.2 SIXCONs

The results show that as the mean number of SIXCON reports sent per day increases, both the mean (Figure 4-24, Figure 4-25, Figure 4-26, and Figure 4-27) and maximum (Figure 4-28, Figure 4-29, Figure 4-30, and Figure 4-31) SIXCON error decrease.

With SIXCONs, the benefits of condition based reporting are very clear. For a given activity level, if an equal number of SIXCON reports are sent per day, the condition based policy will have a lower mean and maximum SIXCON error than the time based policy. A condition based policy can maintain a very low mean and maximum SIXCON error while sending very few reports overall.

![Mean SIXCON Error vs. Mean SIXCON Reports Sent Per Day](image)

Figure 4-24: Mean SIXCON Error vs Mean SIXCON Reports Sent per Day, Unscripted Scenario, Patrol Rate = .25
Figure 4-25: Mean SIXCON Error vs Mean SIXCON Reports Sent per Day, Unscripted Scenario, Patrol Rate = .5

Figure 4-26: Mean SIXCON Error vs Mean SIXCON Reports Sent per Day, Unscripted Scenario, Patrol Rate = .75
Figure 4-27: Mean SIXCON Error vs Mean SIXCON Reports Sent per Day, Scripted Scenario
Figure 4-28: Maximum SIXCON Error vs Mean SIXCON Reports Sent per Day, Unscripted Scenario, Patrol Rate = .25
Figure 4-29: Maximum SIXCON Error vs Mean SIXCON Reports Sent per Day, Unscripted Scenario, Patrol Rate = .5

Figure 4-30: Maximum SIXCON Error vs Mean SIXCON Reports Sent per Day, Unscripted Scenario, Patrol Rate = .75
Figure 4-31: Maximum SIXCON Error vs Mean SIXCON Reports Sent per Day, Scripted Scenario
Chapter 5: Conclusions

5.1 Conclusions

For vehicles, a condition based reporting policy is superior, in some ways, to a time based reporting policy. When the overall reporting volume was low, the condition based reporting was able to maintain a lower maximum vehicle error than the time based reporting. Because of this, the best reporting policy for vehicles will be condition based. It has an advantage over time based reporting but no demonstrated disadvantage.

The difference between the time based policies and condition based policies is relatively small with the vehicles. This is because in these simulations and, to a lesser degree, in real life, the time based policies really are a type of condition based policies. In the simulations, the vehicles burn fuel at a constant rate while they are running. Therefore, the time between reports can be directly converted to a fuel consumption between reports which is equivalent to a reporting condition. The fuel burn is only constant within a patrol. Since patrols have different road types to traverse and different speeds, there is variation within the simulation, which is why there is some benefit to the condition based reporting in the results.

In real situations, there will be much more variation. Vehicles may stop and idle for a period of time and burn very little fuel then go through a period of very aggressive driving with a very high fuel burn rate. It is likely that in such a situation, condition based reporting policies will be more beneficial in decreasing error while maintaining a lower reporting volume.

Even in situations with highly variable fuel consumption rates, the vehicles are still very different from the SIXCONs. Even while idling, a vehicle is burning fuel. Therefore, every time a report is sent, new information is being passed. The report will lower the current vehicle error, even if by a very small margin.
SIXCONs, conversely, can go for extended periods of time with no change to the fuel level. If reports are sent when no change in fuel level has occurred, a cost is incurred (network bandwidth, battery power, etc.) with no benefit at all. This is why, for SIXCONs, a condition based reporting policy is far, far superior to a time based reporting policy. Very low error levels can be maintained while sending relatively few reports.

5.2 Future Research

One area for future research would be to analyze the impact of increased variability in vehicle operation. In this study, vehicle speed and road type were held constant. In real operating environments, these factors and, therefore, the fuel consumption rate change frequently. There are also frequently periods of idling where the fuel consumption will be much lower than during movement. As noted in Section 5.1, this could create a greater difference between time based and conditioned based reporting.

Another area for future work would be to examine some more advanced reporting policies such as a deviation policy similar to the one described in Wolfson and Yin (2003). Instead of simply reporting a fuel quantity, the vehicles could also report the current fuel consumption rate. A database can estimate the fuel level of any vehicle using the last reported fuel level and fuel consumption rate. The vehicle would also keep track of this estimate and only send a report when the estimate deviates from the actual fuel level by some predefined value. A policy such as this could potentially decrease the number of reports sent while maintaining a low error rate.

Finally, future research should examine the impact of communication errors. In this study, it was assumed that if a report was sent, it made it to its destination. In reality this will not always be the case. If some portion of the fuel reports are not making it to the destination, there could be a significant impact on error.
 Appendix A: Unscripted Scenario AutoMod Simulation Code

begin model initialization function

    /* default time unit - hours */
    default distance unit - miles */

    /* open a files for verification data */
    print "category,number,dayOrNight,vehicleAvailable" to "distVerificationData.csv"
    print "use,roadType,distance,speed,dayOrNight" to "tripVerificationData.csv"

    /* the rate at which patrols are sent out */
    /* set V_patrolRate to .5 per hr */

    /* used to decrease the night admin use and patrol rates only 5% of the daytime rate are sent out. */
    set V_nightTimeScalar to .05

    /* on base use rate */
    /* set V_onBaseUseRate to 1 per hr */

    /* set the inter-report time for vehicles */
    /* set V_vehReportInterval to 1000 hr */

    /* set the inter-report time for sixcons */
    /* set V_sixconReportInterval to 1000 hr */

    /* set the condition criteria for vehicle reporting */
    /* given in percentage of tank capacity */
    set V_vehicleCriteria to 1.1

    /* set the condition criteria for SIXCON reporting */
    /* given in gallons */
    set V_sixconCriteria to 1000

    /* Set the time interval that controls how often the SIXCONS check their level. The sensor require battery power, not vehicle, so the level can't be checked near-continuously. */
    set V_sixconTankCheckInterval to .25 hr

    /* set the status update time */
    set V_statusUpdateInterval to 1 min

    /* the sim starts at midnight */
    set V_dayOrNight to "night"

    /* initialize the status variables */
    set C_onBaseUse to 0
    set C_vehiclesOnPatrol to 0
    set C_patrols to 0
    set C_sixconTankChecks to 0

    /* initialize the packet counters */
    set C_totalVehiclePackets to 0
    set C_patrolPackets to 0
    set C_onBaseUsePackets to 0
    set C_idleFuelPackets to 0
    set C_sixconPackets to 0
    set C_patrolStartupPackets to 0
    set C_patrolShutdownPackets to 0
    set C_onBaseStartupPackets to 0
    set C_onBaseShutdownPackets to 0


/* initialize the capacities, levels, and reported levels */
set \( V_{\text{totalVehicleCapacity}} \) to 0
set \( V_{\text{totalSixconCapacity}} \) to 0
set \( V_{\text{movingVehicleCapacity}} \) to 0
set \( V_{\text{runningMovingVehicleCapacity}} \) to 0
set \( V_{\text{totalVehicleLevel}} \) to 0
set \( V_{\text{totalSixconLevel}} \) to 0
set \( V_{\text{movingVehicleLevel}} \) to 0
set \( V_{\text{runningMovingVehicleLevel}} \) to 0
set \( V_{\text{totalVehicleReported}} \) to 0
set \( V_{\text{totalSixconReported}} \) to 0
set \( V_{\text{movingVehicleReported}} \) to 0
set \( V_{\text{runningMovingVehicleReported}} \) to 0

/* create the control loads */
create 1 load of type \( L_{\text{control}} \) to \( P_{\text{vehicleCreation}} \)
create 1 load of type \( L_{\text{control}} \) to \( P_{\text{patrolScheduler}} \)
create 1 load of type \( L_{\text{control}} \) to \( P_{\text{statusCheck}} \)
create 1 load of type \( L_{\text{control}} \) to \( P_{\text{onBaseScheduler}} \)
create 1 load of type \( L_{\text{control}} \) to \( P_{\text{dayNightSwitch}} \)

/* open the UpdateLog file */
print "time, totalError, vehicleError, sixconError, movingVehicleError" to "updateLog.csv"
print "time, sixconPercent, sixconPercentReported, vehiclePercent, vehiclePercentReported, totalPercent, totalPercentReported" to "fuelLevelLog.csv"
return true
end

/* Create the vehicles */
begin \( P_{\text{vehicleCreation}} \) arriving procedure

/* Set the attributes that will be the same for all vehicles */
set priority to 1
/* the fuel level at time 0 is known */
set \( A_{\text{lastUpdateTime}} \) to ac
/* the vehicle is not currently on a patrol or being used on base */
set \( A_{\text{patrolNumber}} \) to 0
set \( A_{\text{aveSpeed}} \) to 0
set \( A_{\text{patrolDistance}} \) to 0
set \( A_{\text{roadType}} \) to "paved"
/* the vehicle have no payload */
set \( A_{\text{payload}} \) to 0

/* Create the AAVs */
/* set the initial attributes */
set load type to \( L_{\text{AAV}} \)
/* AAVs have a 400 gallon fuel tank */
set \( A_{\text{fuelCapacity}} \) to 400
/* start with a full tank */
set \( A_{\text{fuelLevel}} \) to 400
/* the fuel level is known initially */
set \( A_{\text{reportedFuelLevel}} \) to \( A_{\text{fuelLevel}} \)
/* AAVs do not supply fuel and have no SIXCONS */
set \( A_{\text{sixconCapacity}} \) to 0
set \( A_{\text{sixconLevel}} \) to 0
set \( A_{\text{sixconReported}} \) to 0
set \( V_{\text{counter}} \) to 1
while \( V_{\text{counter}} <= 15 \) do begin
   /* Give the AAV an identifying number */
   set \( A_{\text{vehicleNumber}} \) to \( V_{\text{counter}} \)
   /* create the vehicle */
   clone 1 load to \( P_{\text{createdVehicle}} \)
   increment \( V_{\text{counter}} \) by 1
end

/* Create the HMMWVs */
/* set the initial attributes */
set load type to L_HMMWV
/* HMMWVs have a 25 gallon fuel tank */
set A_fuelCapacity to 25
/* start with a full tank */
set A_fuelLevel to 25
/* the fuel level is known initially */
set A_reportedFuelLevel to A_fuelLevel
/* HMMWVs do not supply fuel and have no SIXCONS */
set A_sixconCapacity to 0
set A_sixconLevel to 0
set A_sixconReported to 0
set V_counter to 1
while V_counter <= 32 do begin
    /* Give the HMMWV an identifying number */
    set A_vehicleNumber to V_counter
    /* create the vehicle */
    clone 1 load to P_createdVehicle
    increment V_counter by 1
end

/* Create the LAVs */
/* set the initial attributes */
set load type to L_LAV
/* LAVs have a 52 gallon fuel tank */
set A_fuelCapacity to 52
/* start with a full tank */
set A_fuelLevel to 52
/* the fuel level is known initially */
set A_reportedFuelLevel to A_fuelLevel
/* LAVs do not supply fuel and have no SIXCONS */
set A_sixconCapacity to 0
set A_sixconLevel to 0
set A_sixconReported to 0
set V_counter to 1
while V_counter <= 8 do begin
    /* Give the LAV an identifying number */
    set A_vehicleNumber to V_counter
    /* create the vehicle */
    clone 1 load to P_createdVehicle
    increment V_counter by 1
end

/* Create the LVSs */
/* set the initial attributes */
set load type to L_LVS
/* LVSs have a 150 gallon fuel tank */
set A_fuelCapacity to 150
/* start with a full tank */
set A_fuelLevel to 150
/* the fuel level is known initially */
set A_reportedFuelLevel to A_fuelLevel
/* set the capacity of the SIXCONS, each LVS has 3 SIXCONS for a total capacity of 2700 gallons */
set A_sixconCapacity to 2700
/* the SIXCONS are initially full */
set A_sixconLevel to 2700
/* the level is initially known */
set A_sixconReported to 2700
set V_counter to 1
while V_counter <= 2 do begin
    /* Give the LVS an identifying number */
    set A_vehicleNumber to V_counter
    /* create the vehicle */
    clone 1 load to P_createdVehicle
    increment V_counter by 1
end
/* Create the M1A1s */
/* set the initial attributes */
set load type to L_M1A1
/* M1A1s have a 500 gallon tank */
set A_fuelCapacity to 500
/* start with a full tank */
set A_fuelLevel to 500
/* the fuel level is known initially */
set A_reportedFuelLevel to A_fuelLevel
/* M1A1s do not supply fuel and have no SIXCONS */
set A_sixconCapacity to 0
set A_sixconLevel to 0
set A_sixconReported to 0
set V_counter to 1
while V_counter <= 4 do begin
  /* Give the M1A1 an identifying number */
  set A_vehicleNumber to V_counter
  /* create the vehicle */
  clone 1 load to P_createdVehicle
  increment V_counter by 1
end

/* Create the MTVRs */
/* MTVRs have a 78 gallon tank */
set A_fuelCapacity to 78
/* start with a full tank */
set A_fuelLevel to 78
/* the fuel level is known initially */
set A_reportedFuelLevel to A_fuelLevel
set V_counter to 1
while V_counter <= 24 do begin
  /* set the initial attributes */
  set load type to L_MTVR
  /* 6 of the 24 MTVRs provide fuel to other vehicles */
  if V_counter == 1 then begin
    /* This vehicle has 1 SIXCON to provide fuel */
    set A_sixconCapacity to 900
    /* The SIXCON is initially full */
    set A_sixconLevel to 900
    /* the level is initially known */
    set A_sixconReported to 900
  end
else if V_counter == 2 then begin
  /* This vehicle has 1 SIXCON to provide fuel */
  set A_sixconCapacity to 900
  /* The SIXCON is initially full */
  set A_sixconLevel to 900
  /* the level is initially known */
  set A_sixconReported to 900
end
else if V_counter == 3 then begin
  /* This vehicle has 1 SIXCON to provide fuel */
  set A_sixconCapacity to 900
  /* The SIXCON is initially full */
  set A_sixconLevel to 900
  /* the level is initially known */
  set A_sixconReported to 900
end
else if V_counter == 4 then begin
  /* This vehicle has 2 SIXCONS to provide fuel */
  set A_sixconCapacity to 1800
  /* The SIXCONs are initially full */
  set A_sixconLevel to 1800
  /* the level is initially known */
  set A_sixconReported to 1800
end
else if V_counter == 5 then begin
/* This vehicle has 2 SIXCONs to provide fuel */
set A_sixconCapacity to 1800
/* The SIXCON is initially full */
set A_sixconLevel to 1800
/* the level is initially known */
set A_sixconReported to 1800

else if V_counter == 6 then begin
/* This vehicle has 2 SIXCONs to provide fuel */
set A_sixconCapacity to 1800
/* The SIXCON is initially full */
set A_sixconLevel to 1800
/* the level is initially known */
set A_sixconReported to 1800

end

else begin
/* The rest of the MTVRs are not fuel suppliers and have no SIXCONs */
set A_sixconCapacity to 0
set A_sixconLevel to 0
set A_sixconReported to 0

end

/* Give the MTVR an identifying number */
set A_vehicleNumber to V_counter

/* create the vehicle */
clone 1 load to P_createdVehicle
increment V_counter by 1

end

/* done with the creator load */
set type to L_control

wait for 1 sec

/* write the vehicle groups to an output file for verification */
print "moving vehicle group" to "vehicleGroups.txt"
for each V_load in V_movingVehicleGroup do begin
print "t", V_load type, V_load A_vehicleNumber to "vehicleGroups.txt"
end

print "fuel supplier group" to "vehicleGroups.txt"
for each V_load in V_fuelSupplierGroup do begin
print "t", V_load type, V_load A_vehicleNumber to "vehicleGroups.txt"
end

/* wait until the end of the simulation */
wait for 30 * 24 - .00001 - ac hr

/* calculate and store the mean moving vehicle error */
tabulate (V_runningMovingVehicleReported - V_runningMovingVehicleLevel) / V_runningMovingVehicleCapacity * 100 in T_meanMovingVehicleError

send to die

/* Put the newly created vehicles on to the vehicle Order List */
begin P_createdVehicle arriving procedure

/* add this vehicle's fuel to the totals */
set V_totalVehicleCapacity to V_totalVehicleCapacity + A_fuelCapacity
set V_totalVehicleLevel to V_totalVehicleLevel + A_fuelLevel
set V_totalVehicleReported to V_totalVehicleReported + A_reportedFuelLevel

/* if it is a fuel supplier add those numbers to the totals */
if A_sixconCapacity > 0 then begin
set V_totalSixconCapacity to V_totalSixconCapacity + A_sixconCapacity
set V_totalSixconLevel to V_totalSixconLevel + A_sixconLevel
set V_totalSixconReported to V_totalSixconReported + A_sixconReported
end

/* add it to the appropriate group */
if A_sixconCapacity == 0 then begin
insert this into V_movingVehicleGroup at end
print ac, ":", type, A_vehicleNumber,
"is created and added to the Moving Vehicle Group" to "entityCreation.txt"
end
else begin
insert this into V_fuelSupplierGroup at end
print ac, ":", type, A_vehicleNumber,
"is created and added to the Fuel Supplier Group" to "entityCreation.txt"
end

/* send the fuel suppliers to their process */
if A_sixconCapacity > 0 then send to P_idleFuelSupplier

/* Put the vehicle on the vehicle order list */
wait to be ordered on OL_idleVehicles
end

/* Takes parameters: theVehicle (loadPtr) */
begin F_calcFuelUse function

/* Fuel Function for AAVs */
if theVehicle type is L_AAV then begin
if theVehicle A_roadType is "paved" then begin
set V_result to
theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
/ (1 * (1 - theVehicle A_payload / 90000) - .02 * 
theVehicle A_aveSpeed / 45) /* adjusted mpg */
end
else if theVehicle A_roadType is "hard" then begin
set V_result to
theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
/ (.75 * (1 - theVehicle A_payload / 90000) - .02 * 
theVehicle A_aveSpeed / 35) /* adjusted mpg */
end
else if theVehicle A_roadType is "soft" then begin
set V_result to
theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
/ (.5 * (1 - theVehicle A_payload / 90000) - .02 * 
theVehicle A_aveSpeed / 35) /* adjusted mpg */
end
else begin
print ac, ": Error in F_calcFuelUse, type == L_AAV -> invalid road type"
to "errorLog.txt"
end

/* Fuel Function for HMMWVs */
else if theVehicle type is L_HMMWV then begin
if theVehicle A_roadType is "paved" then begin
set V_result to
theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
/ (10 * (1 - theVehicle A_payload / 20000) - 1 * 
theVehicle A_aveSpeed / 45) /* adjusted mpg */
end
else if theVehicle A_roadType is "hard" then begin
set V_result to
theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
/ (8 * (1 - theVehicle A_payload / 20000) - 1 * 
theVehicle A_aveSpeed / 35) /* adjusted mpg */
end
else if theVehicle A_roadType is "soft" then begin
set V_result to
theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
/ (3 * (1 - theVehicle A_payload / 20000) - 1 *
end

else begin
print ac, ": Error in F_calcFuelUse, type == L_HMMWV -> invalid road type"
to "errorLog.txt"
end

/* Fuel Function for LAVs */
else if theVehicle type is L_LAV then begin
if theVehicle A_roadType is "paved" then begin
set V_result to
theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
/ (7.5 * (1 - theVehicle A_payload / 20000) - .5 *
theVehicle A_aveSpeed / 45) /* adjusted mpg */
end

else if theVehicle A_roadType is "hard" then begin
set V_result to
theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
/ (6 * (1 - theVehicle A_payload / 20000) - .5 *
theVehicle A_aveSpeed / 35) /* adjusted mpg */
end

else if theVehicle A_roadType is "soft" then begin
set V_result to
theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
/ (1 * (1 - theVehicle A_payload / 20000) - .5 *
theVehicle A_aveSpeed / 25) /* adjusted mpg */
end

else begin
print ac, ": Error in F_calcFuelUse, type == L_LAV -> invalid road type"
to "errorLog.txt"
end

/* Fuel Function for LVs */
else if theVehicle type is L_LVS then begin
if theVehicle A_roadType is "paved" then begin
set V_result to
theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
/ (3 * (1 - theVehicle A_payload / 20000) - .02 *
theVehicle A_aveSpeed / 45) /* adjusted mpg */
end

else if theVehicle A_roadType is "hard" then begin
set V_result to
theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
/ (2.5 * (1 - theVehicle A_payload / 20000) - .02 *
theVehicle A_aveSpeed / 35) /* adjusted mpg */
end

else if theVehicle A_roadType is "soft" then begin
set V_result to
theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
/ (1 * (1 - theVehicle A_payload / 20000) - .02 *
theVehicle A_aveSpeed / 25) /* adjusted mpg */
end

else begin
print ac, ": Error in F_calcFuelUse, type == L_LVS -> invalid road type"
to "errorLog.txt"
end

/* Fuel Function for M1A1s */
else if theVehicle type is L_M1A1 then begin
    if theVehicle A_roadType is "paved" then begin
        set V_result to
        theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
        / (.3 * (1 - theVehicle A_payload / 20000) - .001 * theVehicle A_aveSpeed / 45) /* adjusted mpg */
    end
    else if theVehicle A_roadType is "hard" then begin
        set V_result to
        theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
        / (.25 * (1 - theVehicle A_payload / 20000) - .001 * theVehicle A_aveSpeed / 35) /* adjusted mpg */
    end
    else if theVehicle A_roadType is "soft" then begin
        set V_result to
        theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
        / (.2 * (1 - theVehicle A_payload / 20000) - .001 * theVehicle A_aveSpeed / 25) /* adjusted mpg */
    end
    else begin
        print ac, ": Error in F_calcFuelUse, type == L_M1A1 -> invalid road type" to "errorLog.txt"
    end
end

/* Fuel Function for MTVRs */
else if theVehicle type is L_MTVR then begin
    if theVehicle A_roadType is "paved" then begin
        set V_result to
        theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
        / (4 * (1 - theVehicle A_payload / 80000) - .05 * theVehicle A_aveSpeed / 45) /* adjusted mpg */
    end
    else if theVehicle A_roadType is "hard" then begin
        set V_result to
        theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
        / (3.5 * (1 - theVehicle A_payload / 80000) - .05 * theVehicle A_aveSpeed / 35) /* adjusted mpg */
    end
    else if theVehicle A_roadType is "soft" then begin
        set V_result to
        theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
        / (1 * (1 - theVehicle A_payload / 80000) - .05 * theVehicle A_aveSpeed / 25) /* adjusted mpg */
    end
    else begin
        print ac, ": Error in F_calcFuelUse, type == L_MTVR -> invalid road type" to "errorLog.txt"
    end
end

else begin
    print ac, ": Error in F_calcFuelUse -> invalid vehicle type" to "errorLog.txt"
end

return V_result
end

/* Fuel Function for AAVs */
begin F_calcNextConditionTime function
if theVehicle type is L_AAV then begin
    if theVehicle A_roadType is "paved" then begin
        set V_result to
        theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
        / (.3 * (1 - theVehicle A_payload / 20000) - .001 * theVehicle A_aveSpeed / 45) /* adjusted mpg */
    end

    else if theVehicle A_roadType is "hard" then begin
        set V_result to
        theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
        / (.25 * (1 - theVehicle A_payload / 20000) - .001 * theVehicle A_aveSpeed / 35) /* adjusted mpg */
    end

    else if theVehicle A_roadType is "soft" then begin
        set V_result to
        theVehicle A_aveSpeed * (ac - theVehicle A_lastUpdateTime) /* dist travelled */
        / (.2 * (1 - theVehicle A_payload / 20000) - .001 * theVehicle A_aveSpeed / 25) /* adjusted mpg */
    end

    else begin
        print ac, ": Error in F_calcFuelUse, type == L_AAV -> invalid road type"
    end
end

return V_result
end

begin F_calcNextConditionTime function
/* Fuel Function for AAIs */
if theVehicle type is L_AAI then begin
    if theVehicle A_roadType is "paved" then begin
```
set V_nextCriteriaTime to ac +
  (1 * (1 - theVehicle A_payload / 90000) - .02 * 
    theVehicle A_aveSpeed / 45) /* adjusted mpg */ / 
  * theVehicle A_fuelCapacity * V_vehicleCriteria /* criteria volume */ / 
  / theVehicle A_aveSpeed /* average speed */
end

else if theVehicle A_roadType is "hard" then begin
  set V_nextCriteriaTime to ac +
    (.75 * (1 - theVehicle A_payload / 90000) - .02 *
     theVehicle A_aveSpeed / 35) /* adjusted mpg */ / 
     * theVehicle A_fuelCapacity * V_vehicleCriteria /* criteria volume */ / 
    / theVehicle A_aveSpeed /* average speed */
end

else if theVehicle A_roadType is "soft" then begin
  set V_nextCriteriaTime to ac +
    (.5 * (1 - theVehicle A_payload / 90000) - .02 *
     theVehicle A_aveSpeed / 25) /* adjusted mpg */ / 
     * theVehicle A_fuelCapacity * V_vehicleCriteria /* criteria volume */ / 
    / theVehicle A_aveSpeed /* average speed */
end
else begin
  print ac, ": Error in F_calcFuelUse, type == L_AAV -> invalid road type"
  to "errorLog.txt"
end

/* Fuel Function for LAVs */
else if theVehicle type is L_LAV then begin
  if theVehicle A_roadType is "paved" then begin
    set V_nextCriteriaTime to ac +
      (7.5 * (1 - theVehicle A_payload / 20000) - .5 *
       theVehicle A_aveSpeed / 45) /* adjusted mpg */ / 
       * theVehicle A_fuelCapacity * V_vehicleCriteria /* criteria volume */ / 
      / theVehicle A_aveSpeed /* average speed */
  end

  else if theVehicle A_roadType is "hard" then begin
    set V_nextCriteriaTime to ac +
      (6 * (1 - theVehicle A_payload / 20000) - .5 *
       theVehicle A_aveSpeed / 35) /* adjusted mpg */ / 
       * theVehicle A_fuelCapacity * V_vehicleCriteria /* criteria volume */ / 
      / theVehicle A_aveSpeed /* average speed */
  end

  else if theVehicle A_roadType is "soft" then begin
    set V_nextCriteriaTime to ac +
      (1 * (1 - theVehicle A_payload / 20000) - .5 *
       theVehicle A_aveSpeed / 25) /* adjusted mpg */ / 
       * theVehicle A_fuelCapacity * V_vehicleCriteria /* criteria volume */ / 
      / theVehicle A_aveSpeed /* average speed */
  end

  else begin
    print ac, ": Error in F_calcFuelUse, type == L_LAV -> invalid road type"
    to "errorLog.txt"
  end
end

/* Fuel Function for HMMWVs */
else if theVehicle type is L_HMMWV then begin
  if theVehicle A_roadType is "paved" then begin
    set V_nextCriteriaTime to ac +
      (10 * (1 - theVehicle A_payload / 20000) - 1 *
       theVehicle A_aveSpeed / 45) /* adjusted mpg */ / 
       * theVehicle A_fuelCapacity * V_vehicleCriteria /* criteria volume */ / 
      / theVehicle A_aveSpeed /* average speed */
  end

  else if theVehicle A_roadType is "hard" then begin
    set V_nextCriteriaTime to ac +
      (9 * (1 - theVehicle A_payload / 20000) - 1 *
       theVehicle A_aveSpeed / 35) /* adjusted mpg */ / 
       * theVehicle A_fuelCapacity * V_vehicleCriteria /* criteria volume */ / 
      / theVehicle A_aveSpeed /* average speed */
  end

  else if theVehicle A_roadType is "soft" then begin
    set V_nextCriteriaTime to ac +
      (1 * (1 - theVehicle A_payload / 20000) - .5 *
       theVehicle A_aveSpeed / 25) /* adjusted mpg */ / 
       * theVehicle A_fuelCapacity * V_vehicleCriteria /* criteria volume */ / 
      / theVehicle A_aveSpeed /* average speed */
  end

  else begin
    print ac, ": Error in F_calcFuelUse, type == L_HMMWV -> invalid road type"
    to "errorLog.txt"
  end
end
```
else if theVehicle A_roadType is "hard" then begin
    set V_nextCriteriaTime to ac +
    (8 * (1 - theVehicle A_payload / 20000) - 1 *
        theVehicle A_aveSpeed / 35) /* adjusted mpg */
        * theVehicle A_fuelCapacity * V_vehicleCriteria /* criteria volume */
        / theVehicle A_aveSpeed /* average speed */
end

else if theVehicle A_roadType is "soft" then begin
    set V_nextCriteriaTime to ac +
    (3 * (1 - theVehicle A_payload / 20000) - 1 *
        theVehicle A_aveSpeed / 25) /* adjusted mpg */
        * theVehicle A_fuelCapacity * V_vehicleCriteria /* criteria volume */
        / theVehicle A_aveSpeed /* average speed */
end

else begin
    print ac, ": Error in F_calcFuelUse, type == L_HMMWV -> invalid road type"
    to "errorLog.txt"
end

/* Fuel Function for LVSSs */
else if theVehicle type is L_LVS then begin
    if theVehicle A_roadType is "paved" then begin
        set V_nextCriteriaTime to ac +
        (3 * (1 - theVehicle A_payload / 20000) - .02 *
            theVehicle A_aveSpeed / 45) /* adjusted mpg */
            * theVehicle A_fuelCapacity * V_vehicleCriteria /* criteria volume */
            / theVehicle A_aveSpeed /* average speed */
end

    else if theVehicle A_roadType is "hard" then begin
        set V_nextCriteriaTime to ac +
        (2.5 * (1 - theVehicle A_payload / 20000) - .02 *
            theVehicle A_aveSpeed / 35) /* adjusted mpg */
            * theVehicle A_fuelCapacity * V_vehicleCriteria /* criteria volume */
            / theVehicle A_aveSpeed /* average speed */
end

    else if theVehicle A_roadType is "soft" then begin
        set V_nextCriteriaTime to ac +
        (1 * (1 - theVehicle A_payload / 20000) - .02 *
            theVehicle A_aveSpeed / 25) /* adjusted mpg */
            * theVehicle A_fuelCapacity * V_vehicleCriteria /* criteria volume */
            / theVehicle A_aveSpeed /* average speed */
end

    else begin
        print ac, ": Error in F_calcFuelUse, type == L_LVS -> invalid road type"
        to "errorLog.txt"
end

/* Fuel Function for M1A1s */
else if theVehicle type is L_M1A1 then begin
    if theVehicle A_roadType is "paved" then begin
        set V_nextCriteriaTime to ac +
        (.3 * (1 - theVehicle A_payload / 20000) - .001 *
            theVehicle A_aveSpeed / 45) /* adjusted mpg */
            * theVehicle A_fuelCapacity * V_vehicleCriteria /* criteria volume */
            / theVehicle A_aveSpeed /* average speed */
end

    else if theVehicle A_roadType is "hard" then begin
        set V_nextCriteriaTime to ac +
        (2.5 * (1 - theVehicle A_payload / 20000) - .02 *
            theVehicle A_aveSpeed / 35) /* adjusted mpg */
            * theVehicle A_fuelCapacity * V_vehicleCriteria /* criteria volume */
            / theVehicle A_aveSpeed /* average speed */
end

    else if theVehicle A_roadType is "soft" then begin
        set V_nextCriteriaTime to ac +
        (1 * (1 - theVehicle A_payload / 20000) - .02 *
            theVehicle A_aveSpeed / 25) /* adjusted mpg */
            * theVehicle A_fuelCapacity * V_vehicleCriteria /* criteria volume */
            / theVehicle A_aveSpeed /* average speed */
end

    else begin
        print ac, ": Error in F_calcFuelUse, type == L_M1A1 -> invalid road type"
        to "errorLog.txt"
end
begin

else if theVehicle_A_roadType is "soft" then begin
  set V_nextCriteriaTime to ac +
  (.25 * (1 - theVehicle_A_payload / 20000) - .001 *
  theVehicle_A_aveSpeed / 35) /* adjusted mpg */
  * theVehicle_A_fuelCapacity * V_vehicleCriteria /* criteria volume */
  / theVehicle_A_aveSpeed /* average speed */
end

else if theVehicle_A_roadType is "soft" then begin
  set V_nextCriteriaTime to ac +
  (.2 * (1 - theVehicle_A_payload / 20000) - .001 *
  theVehicle_A_aveSpeed / 25) /* adjusted mpg */
  * theVehicle_A_fuelCapacity * V_vehicleCriteria /* criteria volume */
  / theVehicle_A_aveSpeed /* average speed */
end

else begin
  print ac, ": Error in F_calcFuelUse, type == L_M1A1 -> invalid road type"
  to "errorLog.txt"
end

/* Fuel Function for MTVRs */
else if theVehicle_A_type is L_MTVR then begin
  if theVehicle_A_roadType is "paved" then begin
    set V_nextCriteriaTime to ac +
    (4 * (1 - theVehicle_A_payload / 80000) - .05 *
    theVehicle_A_aveSpeed / 45) /* adjusted mpg */
    * theVehicle_A_fuelCapacity * V_vehicleCriteria /* criteria volume */
    / theVehicle_A_aveSpeed /* average speed */
  end

else if theVehicle_A_roadType is "hard" then begin
  set V_nextCriteriaTime to ac +
  (3.5 * (1 - theVehicle_A_payload / 80000) - .05 *
  theVehicle_A_aveSpeed / 35) /* adjusted mpg */
  * theVehicle_A_fuelCapacity * V_vehicleCriteria /* criteria volume */
  / theVehicle_A_aveSpeed /* average speed */
end

else if theVehicle_A_roadType is "soft" then begin
  set V_nextCriteriaTime to ac +
  (1 * (1 - theVehicle_A_payload / 80000) - .05 *
  theVehicle_A_aveSpeed / 25) /* adjusted mpg */
  * theVehicle_A_fuelCapacity * V_vehicleCriteria /* criteria volume */
  / theVehicle_A_aveSpeed /* average speed */
end

else begin
  print ac, ": Error in F_calcFuelUse, type == L_MTVR -> invalid road type"
  to "errorLog.txt"
end

else begin
  print ac, ": Error in F_calcFuelUse -> invalid vehicle type" to "errorLog.txt"
end

return V_nextCriteriaTime

begin P_onBaseScheduler arriving procedure
  while 1=1 do begin
    /* wait to send out the next vehicle */
    set V_onBaseInterArrival to e (1 / V_onBaseUseRate)
    wait for V_onBaseInterArrival
    /* send the vehicle if it is day time. If it is night time, it depends
    on the variable that indicates the probability of a vehicle going out
    at night. Currently, the night time rate is 5% of the day time rate */
  end

end
if V_dayOrNight == "day" or uniform .5, .5 <= V_nightTimeScalar then begin
  order 1 load satisfying type == L_HMMWV
  from OL_idleVehicles to P_onBaseUse
  /* write the data to a file for verification */
  in case order not filled begin
    print "interOnBaseUse," V_onBaseInterArrival, ",", V_dayOrNight, ",no"
    to "distVerificationData.csv"
    continue
  end
end

begin P_onBaseUse arriving procedure
  /* write the data to a file for verification */
  print "interOnBaseUse," V_onBaseInterArrival, ",", V_dayOrNight, ",yes"
  to "distVerificationData.csv"

  /* determine road type */
  set A_roadType to oneof(1:"paved", 2:"hard", 1:"soft")

  /* set the length of the trip (2 - 8 miles) */
  set V_distance to uniform 5,3 mi

  /* set the average speed (10 - 30 mph) */
  set A_aveSpeed to uniform 20,10 mi per hr

  /* set the return time */
  set A_returnTime to (ac + V_distance / A_aveSpeed)

  /* write the trip data for verification */
  print "onBaseUse," A_roadType, "," V_distance, "," A_aveSpeed, ",", V_dayOrNight to "tripVerificationData.csv"

  /* send startup report */
  call F_sendVehicleReport(type, "onBase")
  increment C_onBaseStartupPackets by 1
  set A_reportedFuelLevel to A_fuelLevel
  set A_lastUpdateTime to ac

  /* The vehicle starts driving */
  increment C_onBaseUse by 1
  insert this load into V_onBaseUseLoadList at end
  set A_moving to true
  print ac, ",", type, A_vehicleNumber, "departs" to "onBaseUseLog.txt"
  print ac, ",", type, A_vehicleNumber, "departs" to "onBaseUseLog_detailed.txt"

  /* Determine the next report time. This sets the A_nextReportTime attribute */
  call F_setNextVehicleReportTime(this)

  /* while the vehicle is out, send reports at the specified interval */
  while A_returnTime > A_nextReportTime do begin
    /* wait until the next report time */
    wait for (A_nextReportTime - ac)
    /* calculate the amount of fuel used */
    set V_fuelUsed to F_calcFuelUse(this)
    /* adjust the amount of fuel in the tank */
    set A_fuelLevel to A_fuelLevel - V_fuelUsed
    /* send a report now */
    call F_sendVehicleReport(type, "onBase")
    set A_reportedFuelLevel to A_fuelLevel
    set A_lastUpdateTime to ac
    print ac, "," type, A_vehicleNumber,
    "sends fuel status report - has", A_fuelLevel, "remaining"
    to "onBaseUseLog_detailed.txt"

    /* Determine the next report time. This sets the A_nextReportTime attribute */
    call F_setNextVehicleReportTime(this)
  end
/* drive the last portion of the patrol */
wait for (A_returnTime - ac)
/* calculate the amount of fuel used */
set V_fuelUsed to F_calcFuelUse(this)
/* adjust the amount of fuel in the tank */
set A_fuelLevel to A_fuelLevel - V_fuelUsed
set A_lastUpdateTime to ac
print ac, ":", type, A_vehicleNumber,
"sends fuel status report - has", A_fuelLevel, "remaining"
to "onBaseUseLog_detailed.txt"

/* the vehicle refills its fuel tank if necessary */
if A_fuelLevel < A_fuelCapacity * .75 then begin
    /* send shutdown report */
call F_sendVehicleReport(type, "onBase")
increment C_onBaseShutdownPackets by 1
    /* get fuel */
call F_pumpFuel(this)
    /* send startup report */
call F_sendVehicleReport(type, "onBase")
increment C_onBaseStartupPackets by 1
set A_reportedFuelLevel to A_fuelLevel
set A_lastUpdateTime to ac
print ac, ":", type, A_vehicleNumber, "refills its tank"
to "onBaseUseLog_detailed.txt"
end

/* the vehicle has completed its trip */
print ac, ":", type, A_vehicleNumber, "has completed its trip"
to "onBaseUseLog.txt"
print ac, ":", type, A_vehicleNumber, "has completed its trip"
to "onBaseUseLog_detailed.txt"

/* the distance travelled from fuel station to parking area is
considered negligible and not included in the simulation */

/* the vehicle sends a shutdown report */
call F_sendVehicleReport(type, "onBase")
increment C_onBaseShutdownPackets by 1
set A_reportedFuelLevel to A_fuelLevel
set A_lastUpdateTime to ac

/* the vehicle is no longer in use */
set A_aveSpeed to 0
decrement C_onBaseUse by 1
remove this from V_onBaseUseLoadList
set A_moving to false
wait to be ordered on OL_idleVehicles

begin F_patrolReturn function
    /* print the patrol's return to the patrol log */
    print ac, ": Patrol", patrolNumber, "returns" to "patrolLog.txt"
    print ac, ": Patrol", patrolNumber, "returns" to "patrolLog_detailed.txt"
    /* decrement the number of patrols that are out */
    decrement C_patrols by 1
    return true
end

begin F_sendVehicleReport function
    if usage == "patrol" then increment C_patrolPackets by 1
    if usage == "onBase" then increment C_onBaseUsePackets by 1


increment C_totalVehiclePackets by 1
return true
end

begin F_sendSixconReport function
increment C_sixconPackets by numberOfSixcons
return true
end

begin F_updateFuelTotals
set V_totalVehicleLevel to V_totalVehicleLevel + theVehicleA_fuelLevel
set V_totalVehicleReported to V_totalVehicleReported + theVehicleA_reportedFuelLevel
if theVehicleA_moving == true then begin
set V_movingVehicleLevel to V_movingVehicleLevel + theVehicleA_fuelLevel
set V_movingVehicleReported to V_movingVehicleReported + theVehicleA_reportedFuelLevel
set V_movingVehicleCapacity to V_movingVehicleCapacity + theVehicleA_fuelCapacity
set V_runningMovingVehicleLevel to V_runningMovingVehicleLevel + theVehicleA_fuelLevel
set V_runningMovingVehicleReported to V_runningMovingVehicleReported + theVehicleA_reportedFuelLevel
set V_runningMovingVehicleCapacity to V_runningMovingVehicleCapacity + theVehicleA_fuelCapacity
end
if (theVehicleA_sixconCapacity > 0 and theVehicleA_sixconReported >= theVehicleA_sixconLevel) then begin
set V_totalSixconLevel to V_totalSixconLevel + theVehicleA_sixconLevel
set V_totalSixconReported to V_totalSixconReported + theVehicleA_sixconReported
set V_totalSixconCapacity to V_totalSixconCapacity + theVehicleA_sixconCapacity
end
return true
end

begin F_fuelTotalsTally
set V_totalVehicleCapacity to V_totalVehicleCapacity + V_totalSixconCapacity
set V_totalFuelLevel to V_totalVehicleLevel + V_totalSixconLevel
set V_totalFuelReported to V_totalVehicleReported + V_totalSixconReported
/* change capacities that equal 0 to some other value to avoid NaN results. Done for cases where there are no moving vehicles or in the unlikely event that all sixcons have been resupplied but not reported yet. */
if V_movingVehicleCapacity == 0 then set V_movingVehicleCapacity to 1
if V_totalSixconCapacity == 0 then set V_totalSixconCapacity to 1
set V_vehicleError to (V_totalVehicleReported - V_totalVehicleLevel) / V_totalVehicleCapacity * 100
set V_movingVehicleError to (V_movingVehicleReported - V_movingVehicleLevel) / V_movingVehicleCapacity * 100
set V_sixconError to (V_totalSixconReported - V_totalSixconLevel) / V_totalSixconCapacity * 100
set V_totalError to (V_totalFuelReported - V_totalFuelLevel) / V_totalFuelCapacity * 100
tabulate V_vehicleError in T_vehicleError
tabulate V_sixconError in T_sixconError
tabulate V_totalError in T_totalError
tabulate V_movingVehicleError in T_movingVehicleError
return true
end
begin F_pumpFuel function
    /* determine the amount of fuel needed */
    set V_fuelUsed to theVehicle A_fuelCapacity - theVehicle A_fuelLevel

    print ac, ":", theVehicle type, theVehicle A_vehicleNumber, "needs fuel" to "pumpLog.txt"

    choose a load from among V_fuelSupplierGroup
        whose A_sixconLevel >= V_fuelUsed
    save choice as V_fuelSupplier

    /* if none of the fuel suppliers in the group have sufficient
    fuel, print an error message */
    if V_fuelSupplier == null then begin
        print "No fuel available" to "pumpLog.txt"
        print ac, ": fuel shortage with vehicle", theVehicle type,
           theVehicle A_vehicleNumber to "errorLog.txt"
    end
    else begin
        /* take the fuel from the sixcon */
        set V_fuelSupplier A_sixconLevel to
            V_fuelSupplier A_sixconLevel - V_fuelUsed
        print "pumped from", V_fuelSupplier type,
            V_fuelSupplier A_vehicleNumber, "- reported:",
            V_fuelSupplier A_sixconReported, " - true:",
            V_fuelSupplier A_sixconLevel to "pumpLog.txt"

        /* if the sixcon reaches an arbitrarily low level, it will
        instantaneously refill */
        if V_fuelSupplier A_sixconLevel <
            V_fuelSupplier A_sixconCapacity * .2 then begin
            set V_fuelSupplier A_sixconLevel to
                V_fuelSupplier A_sixconCapacity
            print ac, ":", V_fuelSupplier type, V_fuelSupplier A_vehicleNumber,
                "receives a resupply of fuel for its SIXCONs" to "pumpLog.txt"
        end
    end

    /* add the fuel to the vehicle */
    set theVehicle A_fuelLevel to theVehicle A_fuelCapacity

    return true
end

begin F_setNextVehicleReportTime function
    set V_nextConditionTime to F_calcNextConditionTime(theVehicle)
    if V_nextConditionTime < (ac + V_vehReportInterval) then begin
        set theVehicle A_nextReportTime to V_nextConditionTime
    end
    else begin
        set theVehicle A_nextReportTime to (ac + V_vehReportInterval)
    end

    return true
end

/* fuel supply vehicles will be sending packets even when they
aren't being driven */
begin P_idleFuelSupplier arriving procedure
    while 1=1 do begin
        wait for V_sixconTankCheckInterval
        /* check the tank level */
        increment C_sixconTankChecks by (A_sixconCapacity / 900)
        /* send a time or condition based report, if necessary */
        if ac >= A_lastUpdateTime + V_sixconReportInterval
/* or $A_{sixconLevel} <= A_{sixconReported} - V_{sixconCriteria} * A_{sixconCapacity} / 900$ */ then begin
/* send reports and count the packets */
set $A_{sixconReported} = A_{sixconLevel}$
set $A_{lastUpdateTime} = ac$
call $F_{sendSixconReport}(A_{sixconCapacity} / 900)$
print $ac,,",type,,A_{vehicleNumber},"
"sends a sixcon report" to "pumpLog.txt"
end
end

/* Switches the variable that keeps track of whether it is day or night. This is needed so that there can be different usage rates at day and night. Day is considered 5am to 8pm. */
begin $P_{dayNightSwitch}$ arriving procedure
/* the simulation starts at midnight */
set $V_{dayOrNight} = "night"
wait for 5 hr
set $V_{dayOrNight} = "day"
while 1=1 do begin
  wait for 15 hr
  set $V_{dayOrNight} = "night"
  wait for 9 hr
  set $V_{dayOrNight} = "day"
end
end

begin $P_{patrolScheduler}$ arriving procedure
while 1=1 do begin
  /* time until next patrol leaves */
  set $V_{patrolInterArrival} = e 1 / V_{patrolRate}$
  /* save this number for verification */
  print "interPatrol,,V_{patrolInterArrival},,,V_{dayOrNight},,,yes" to "distVerificationData.csv"
  wait for $V_{patrolInterArrival}$
  /* send the patrol if it is day time. If it is night time, it depends on the variable that indicates the probability of a patrol going out at night. Currently, night patrols go out at 5% of the day time rate */
  if $V_{dayOrNight} == "day"$ or uniform .5, .5 <= $V_{nightTimeScalar}$ then begin
    /* define patrol parameters */
    /* randomly select the road type for the patrol */
    set $V_{roadType} = oneof(1:"paved", 2:"hard", 1:"soft")$
    /* based on road type, set the distance and average speed */
    if $V_{roadType}$ is "paved" then begin
      /* patrol will have an average speed of 20-40mph */
      set $V_{aveSpeed} = uniform 30, 10 mi per hr$
      /* patrol will go a distance of 50-110 miles */
      set $V_{distance} = uniform 80, 30 mi$
    end
    if $V_{roadType}$ is "hard" then begin
      /* patrol will have an average speed of 10-30mph */
      set $V_{aveSpeed} = uniform 20, 10 mi per hr$
      /* patrol will go a distance of 25-85 miles */
      set $V_{distance} = uniform 55, 30 mi$
    end
    if $V_{roadType}$ is "soft" then begin
      /* patrol will have an average speed of 5-15mph */
      set $V_{aveSpeed} = uniform 10, 5 mi per hr$
      /* patrol will go a distance of 15-25 miles */
      set $V_{distance} = uniform 20, 5 mi$
    end
  end
  /* save the patrol data for verification */
  print "patrol,,V_{roadType},,,V_{distance},,,V_{aveSpeed},,,"
V_dayOrNight to "tripVerificationData.csv"

/* order the vehicles to start the patrol */
/* if not enough vehicles are available, the patrol goes on without */

set V_patrolType to oneof (20:"armor", 45:"hmmwv", 10:"mtvrhmmwv", 25:"lav")
if V_patrolType == "armor" then begin
  order (4 + (6-4+1) * uniform .5, .5) loads satisfying type == L_AAV
    from OL_idleVehicles to P_patrol
  order oneof (2:0, 1:2, 1:4) loads satisfying type == L_M1A1
    from OL_idleVehicles to P_patrol
end
else if V_patrolType == "hmmwv" then begin
  order (4 + (6-4+1) * uniform .5, .5) loads satisfying type == L_HMMWV
    from OL_idleVehicles to P_patrol
end
else if V_patrolType == "mtvrhmmwv" then begin
  order (2 + (4-2+1) * uniform .5, .5) loads satisfying type == L_HMMWV
    from OL_idleVehicles to P_patrol
  order (2 + (4-2+1) * uniform .5, .5) loads satisfying type == L_MTVR
    from OL_idleVehicles to P_patrol
end
else if V_patrolType == "lav" then begin
  order (4 + (6-4+1) * uniform .5, .5) loads satisfying type == L_LAV
    from OL_idleVehicles to P_patrol
end
else begin
  print ac, "patrol type error in P_patrolScheduler" to "errorLog.txt"
end

/* 0 to 4 AAVs */
order (0 + (4-0+1) * uniform .5, .5) loads satisfying type == L_AAV
  from OL_idleVehicles to P_patrol
/* 6 to 12 HMMWVs */
order (6 + (12-6+1) * uniform .5, .5) loads satisfying type == L_HMMWV
  from OL_idleVehicles to P_patrol
/* 2 to 4 LAVs */
order (2 + (4-2+1) * uniform .5, .5) loads satisfying type == L_LAV
  from OL_idleVehicles to P_patrol
/* 0 to 4 M1A1s */
order (0 + (4-0+1) * uniform .5, .5) loads satisfying type == L_M1A1
  from OL_idleVehicles to P_patrol
/* 4 to 8 MTVRs - can only choose from the MTVRs that don't supply fuel */
order (4 + (8-4+1) * uniform .5, .5) loads satisfying (type == L_MTVR and A_sixconCapacity == 0)
  from OL_idleVehicles to P_patrol

increment C_patrols by 1
print ac, ": Patrol", C_patrols total as .0, "departs - will go", V_distance, "miles at", V_aveSpeed, "mph on", V_roadType, "surface" to "patrolLog.txt"
print ac, ": Patrol", C_patrols total as .0, "departs - will go", V_distance, "miles at", V_aveSpeed, "mph on", V_roadType, "surface" to "patrolLog_detailed.txt"

schedule at (ac + V_distance/V_aveSpeed + 3/60) priority 1
F_patrolReturn(C_patrols total)

end

begin P_patrol arriving procedure

/* set the attribute that identifies what patrol the vehicle is on */
set A_patrolNumber to C_patrols total

/* set the patrol parameters */
set A_roadType to V_roadType
set A_patrolDistance to V_distance
set A_aveSpeed to V_aveSpeed

/* The vehicles will start over a 3 minute period */
wait for uniform 1.5, 1.5 min

/* the vehicle's movement from the parking area to the fuel station to the
convoy start point are assumed to be negligible and are not included
in the simulation */

/* send startup report */
call F_sendVehicleReport(type, "patrol")
increment C_patrolStartupPackets by 1
set A_reportedFuelLevel to A_fuelLevel
set A_lastUpdateTime to ac

if A_fuelLevel < A_fuelCapacity then begin
  /* send shutdown report */
  call F_sendVehicleReport(type, "patrol")
  increment C_patrolShutdownPackets by 1
  /* get fuel */
  call F_pumpFuel(this)
  /* send startup report */
  call F_sendVehicleReport(type, "patrol")
  increment C_patrolStartupPackets by 1
  set A_reportedFuelLevel to A_fuelLevel
  set A_lastUpdateTime to ac
end

/* set the patrol parameters */
set A_returnTime to (ac + A_patrolDistance / A_aveSpeed)

/* The vehicle departs with the convoy */
increment C_vehiclesOnPatrol by 1
insert this load into V_patrolLoadList at end
set A_moving to true
print ac, ":		", type, A_vehicleNumber, "departs on Patrol", A_patrolNumber
to "patrolLog_detailed.txt"

/* Determine the next report time. This sets the A_nextReportTime attribute */
call F_setNextVehicleReportTime(this)

/* while the convoy is out, send reports at the specified interval */
while A_returnTime > A_nextReportTime do begin
  /* wait until the next report time */
  wait for (A_nextReportTime - ac)
  /* calculate the amount of fuel used */
  set V_fuelUsed to F_calcFuelUse(this)
  /* adjust the amount of fuel in the tank */
  set A_fuelLevel to A_fuelLevel - V_fuelUsed
  /* send a report now */
  call F_sendVehicleReport(type, "patrol")
  set A_reportedFuelLevel to A_fuelLevel
  set A_lastUpdateTime to ac
  print ac, ":		", type, A_vehicleNumber, "on Patrol", A_patrolNumber,
  "sends fuel status report - has", A_fuelLevel, "remaining"
to "patrolLog_detailed.txt"

  /* Determine the next report time. This sets the A_nextReportTime attribute */
call F_setNextVehicleReportTime(this)
end

/* drive the last portion of the patrol */
wait for A_returnTime - ac
/* calculate the amount of fuel used */
set V_fuelUsed to F_calcFuelUse(this)
/* adjust the amount of fuel in the tank */
set A_fuelLevel to A_fuelLevel - V_fuelUsed
set A_lastUpdateTime to ac

print ac, "\\n" type, A_vehicleNumber, "on Patrol", A_patrolNumber, 
"sends fuel status report - has", A_fuelLevel, "remaining" 
to "patrolLog_detailed.txt"

/* the vehicle is no longer on a patrol */
print ac, "\\n" type, A_vehicleNumber, "returns from Patrol", A_patrolNumber 
to "patrolLog_detailed.txt"

/* the vehicle refills its fuel tank */
/* send shutdown report */
call F_sendVehicleReport(type, "patrol")
increment C_patrolShutdownPackets by 1

/* get fuel */
call F_pumpFuel(this) 
/* send startup report */
call F_sendVehicleReport(type, "patrol")
increment C_patrolStartupPackets by 1

/* the vehicle drives to where ever it parks - is assumed to be
negligible and left out of the simulation */

/* the vehicle sends a shutdown report */
call F_sendVehicleReport(type, "patrol")
increment C_patrolShutdownPackets by 1
set A_reportedFuelLevel to A_fuelLevel
set A_lastUpdateTime to ac

print ac, "\\n" type, A_vehicleNumber, "refills its tank and shuts down" 
to "patrolLog_detailed.txt"

decrement C_vehiclesOnPatrol by 1
set A_patrolNumber to 0
set A_aveSpeed to 0
set A_patrolDistance to 0
remove this from V_patrolLoadList
set A_moving to false
wait to be ordered on OL_idleVehicles
end

begin P_statusCheck arriving procedure
/* make sure that the status update is the last thing done */
set priority to 10
while j = 1 do begin
    wait for V_statusUpdateInterval
    /\ update fuel level of the vehicles on patrol */
    for each V_load in V_patrolLoadList do begin
        set V_fuelUsed to F_calcFuelUse(V_load)
        set V_load A_fuelLevel to V_load A_fuelLevel - V_fuelUsed
        set V_load A_lastUpdateTime to ac
    end

    /\ update fuel level of the vehicles being used on base */
    for each V_load in V_onBaseUseLoadList do begin
        set V_fuelUsed to F_calcFuelUse(V_load)
        set V_load A_fuelLevel to V_load A_fuelLevel - V_fuelUsed
        set V_load A_lastUpdateTime to ac
    end

    /* Get the true and reported status */
    set V_totalVehicleReported to 0
    set V_totalVehicleLevel to 0
    set V_movingVehicleReported to 0
    set V_movingVehicleLevel to 0
set V_movingVehicleCapacity to 0
set V_totalSixconLevel to 0
set V_totalSixconReported to 0
set V_totalSixconCapacity to 0

for each V_load in V_movingVehicleGroup do begin
    call F_updateFuelTotals(V_load)
end

for each V_load in V_fuelSupplierGroup do begin
    call F_updateFuelTotals(V_load)
end

call F_fuelTotalsTally()

print ac, ",", V_totalError, ",", V_vehicleError, ",", V_sixconError, ",", V_movingVehicleError to "updateLog.csv"

print ac, ",", V_totalSixconLevel / V_totalSixconCapacity * 100, ",", V_totalSixconReported / V_totalSixconCapacity * 100, ",", V_totalVehicleLevel / V_totalVehicleCapacity * 100, ",", V_totalVehicleReported / V_totalVehicleCapacity * 100, ",", V_totalFuelLevel / V_totalFuelCapacity * 100, ",", V_totalFuelReported / V_totalFuelCapacity * 100

to "fuelLevelLog.csv"
end
Appendix B: Scripted Scenario AutoMod Simulation Code

/* Takes parameters: theVehicle (loadPtr) */
begin F_calcFuelUse function

/* Fuel Function for AAVs */
if theVehicle type is L_AAV then begin
if theVehicle A_roadType is "paved" then begin
set V_result to
theVehicle A_aveSpeed * (ac - theVehicle A_lastVehUpdateTime) /* dist travelled */
/ (1 * (1 - theVehicle A_payload / 90000) - .02 *
theVehicle A_aveSpeed / 45) /* adjusted mpg */
end
else if theVehicle A_roadType is "hard" then begin
set V_result to
theVehicle A_aveSpeed * (ac - theVehicle A_lastVehUpdateTime) /* dist travelled */
/ (.75 * (1 - theVehicle A_payload / 90000) - .02 *
theVehicle A_aveSpeed / 35) /* adjusted mpg */
end
else if theVehicle A_roadType is "soft" then begin
set V_result to
theVehicle A_aveSpeed * (ac - theVehicle A_lastVehUpdateTime) /* dist travelled */
/ (.5 * (1 - theVehicle A_payload / 90000) - .02 *
theVehicle A_aveSpeed / 25) /* adjusted mpg */
end
else begin
print ac, ": Error in F_calcFuelUse, type == L_AAV -> invalid road type"
to "errorLog.txt"
end
end

/* Fuel Function for HMMWVs */
else if theVehicle type is L_HMMWV then begin
if theVehicle A_roadType is "paved" then begin
set V_result to
theVehicle A_aveSpeed * (ac - theVehicle A_lastVehUpdateTime) /* dist travelled */
/ (10 * (1 - theVehicle A_payload / 20000) - 1 *
theVehicle A_aveSpeed / 45) /* adjusted mpg */
end
else if theVehicle A_roadType is "hard" then begin
set V_result to
theVehicle A_aveSpeed * (ac - theVehicle A_lastVehUpdateTime) /* dist travelled */
/ (8 * (1 - theVehicle A_payload / 20000) - 1 *
theVehicle A_aveSpeed / 35) /* adjusted mpg */
end
else if theVehicle A_roadType is "soft" then begin
set V_result to
theVehicle A_aveSpeed * (ac - theVehicle A_lastVehUpdateTime) /* dist travelled */
/ (3 * (1 - theVehicle A_payload / 20000) - 1 *
theVehicle A_aveSpeed / 25) /* adjusted mpg */
end
else begin
print ac, ": Error in F_calcFuelUse, type == L_HMMWV -> invalid road type"
to "errorLog.txt"
end
end

/* Fuel Function for LAVs */
else if theVehicle type is L_LAV then begin
    if theVehicle A_roadType is "paved" then begin
        set V_result to
            theVehicle A_aveSpeed * (ac - theVehicle A_lastVehUpdateTime) /* dist travelled */
            / (7.5 * (1 - theVehicle A_payload / 20000) - .5 *
                theVehicle A_aveSpeed / 45) /* adjusted mpg */
    end

    else if theVehicle A_roadType is "hard" then begin
        set V_result to
            theVehicle A_aveSpeed * (ac - theVehicle A_lastVehUpdateTime) /* dist travelled */
            / (6 * (1 - theVehicle A_payload / 20000) - .5 *
                theVehicle A_aveSpeed / 35) /* adjusted mpg */
    end

    else if theVehicle A_roadType is "soft" then begin
        set V_result to
            theVehicle A_aveSpeed * (ac - theVehicle A_lastVehUpdateTime) /* dist travelled */
            / (1 * (1 - theVehicle A_payload / 20000) - .5 *
                theVehicle A_aveSpeed / 25) /* adjusted mpg */
    end

    else begin
        print ac, ": Error in F_calcFuelUse, type == L_LAV -> invalid road type"
        to "errorLog.txt"
    end
end

/* Fuel Function for LVSs */
else if theVehicle type is L_LVS then begin
    if theVehicle A_roadType is "paved" then begin
        set V_result to
            theVehicle A_aveSpeed * (ac - theVehicle A_lastVehUpdateTime) /* dist travelled */
            / (3 * (1 - theVehicle A_payload / 20000) - .02 *
                theVehicle A_aveSpeed / 45) /* adjusted mpg */
    end

    else if theVehicle A_roadType is "hard" then begin
        set V_result to
            theVehicle A_aveSpeed * (ac - theVehicle A_lastVehUpdateTime) /* dist travelled */
            / (2.5 * (1 - theVehicle A_payload / 20000) - .02 *
                theVehicle A_aveSpeed / 35) /* adjusted mpg */
    end

    else if theVehicle A_roadType is "soft" then begin
        set V_result to
            theVehicle A_aveSpeed * (ac - theVehicle A_lastVehUpdateTime) /* dist travelled */
            / (1 * (1 - theVehicle A_payload / 20000) - .02 *
                theVehicle A_aveSpeed / 25) /* adjusted mpg */
    end

    else begin
        print ac, ": Error in F_calcFuelUse, type == L_LVS -> invalid road type"
        to "errorLog.txt"
    end
end

/* Fuel Function for M1A1s */
else if theVehicle type is L_M1A1 then begin
    if theVehicle A_roadType is "paved" then begin
        set V_result to
            theVehicle A_aveSpeed * (ac - theVehicle A_lastVehUpdateTime) /* dist travelled */
            / (.3 * (1 - theVehicle A_payload / 20000) - .001 *
                theVehicle A_aveSpeed / 45) /* adjusted mpg */
    end

    else if theVehicle A_roadType is "hard" then begin
        set V_result to
begin F_calcFuelUse function

/* Fuel Function for MTVRs */
else if theVehicle type is L_MTVR then begin

if theVehicle A_roadType is "paved" then begin
    set V_result to
    theVehicle A_aveSpeed * (ac - theVehicle A_lastVehUpdateTime) /* dist travelled */
    / (4 * (1 - theVehicle A_payload / 80000) - .05 *
        theVehicle A_aveSpeed / 45) /* adjusted mpg */
end

else if theVehicle A_roadType is "hard" then begin
    set V_result to
    theVehicle A_aveSpeed * (ac - theVehicle A_lastVehUpdateTime) /* dist travelled */
    / (3.5 * (1 - theVehicle A_payload / 80000) - .05 *
        theVehicle A_aveSpeed / 35) /* adjusted mpg */
end

else if theVehicle A_roadType is "soft" then begin
    set V_result to
    theVehicle A_aveSpeed * (ac - theVehicle A_lastVehUpdateTime) /* dist travelled */
    / (1 * (1 - theVehicle A_payload / 80000) - .05 *
        theVehicle A_aveSpeed / 25) /* adjusted mpg */
end

else begin
    print ac, ": Error in F_calcFuelUse, type == L_MTVR -> invalid road type"
    to "errorLog.txt"
end

end

else begin
    print ac, ": Error in F_calcFuelUse, type == L_MTVR -> invalid vehicle type"
    to "errorLog.txt"
end

return V_result
end

begin F_calcNextConditionTime function

/* Fuel Function for AAVs */
if theVehicle type is L_AAV then begin

if theVehicle A_roadType is "paved" then begin
    set V_nextCriteriaTime to ac +
    (1 * (1 - theVehicle A_payload / 90000) - .02 *
        theVehicle A_aveSpeed / 45) /* adjusted mpg */
        * (theVehicle A_fuelCapacity * V_vehicleCriteria
            - theVehicle A_reportedFuelLevel + theVehicle A_fuelLevel)/* criteria volume */
            / theVehicle A_aveSpeed /* average speed */
end

else if theVehicle A_roadType is "hard" then begin
    set V_nextCriteriaTime to ac +
end

return V_nextCriteriaTime
(0.75 * (1 - theVehicle_A_payload / 90000) - 0.02 * theVehicle_A_aveSpeed / 35) /* adjusted mpg */ * (theVehicle_A_fuelCapacity * V_vehicleCriteria - theVehicle_A_reportedFuelLevel + theVehicle_A_fuelLevel) /* criteria volume */ / theVehicle_A_aveSpeed /* average speed */
end

else if theVehicle_A_roadType is "soft" then begin
    set V_nextCriteriaTime to ac +
    (0.5 * (1 - theVehicle_A_payload / 90000) - 0.02 *
    theVehicle_A_aveSpeed / 25) /* adjusted mpg */
    * (theVehicle_A_fuelCapacity * V_vehicleCriteria
    - theVehicle_A_reportedFuelLevel + theVehicle_A_fuelLevel) /* criteria volume */
    / theVehicle_A_aveSpeed /* average speed */
end
else begin
    print ac, ": Error in F_calcFuelUse, type == AAV -> invalid road type"
    to "errorLog.txt"
end

/* Fuel Function for LAVs */
else if theVehicle_type is L_LAV then begin
    if theVehicle_A_roadType is "paved" then begin
        set V_nextCriteriaTime to ac +
        (7.5 * (1 - theVehicle_A_payload / 20000) - 0.5 *
        theVehicle_A_aveSpeed / 45) /* adjusted mpg */
        * (theVehicle_A_fuelCapacity * V_vehicleCriteria
        - theVehicle_A_reportedFuelLevel + theVehicle_A_fuelLevel) /* criteria volume */
        / theVehicle_A_aveSpeed /* average speed */
    end
else if theVehicle_A_roadType is "hard" then begin
    set V_nextCriteriaTime to ac +
    (6 * (1 - theVehicle_A_payload / 20000) - 0.5 *
    theVehicle_A_aveSpeed / 35) /* adjusted mpg */
    * (theVehicle_A_fuelCapacity * V_vehicleCriteria
    - theVehicle_A_reportedFuelLevel + theVehicle_A_fuelLevel) /* criteria volume */
    / theVehicle_A_aveSpeed /* average speed */
end
else if theVehicle_A_roadType is "soft" then begin
    set V_nextCriteriaTime to ac +
    (1 * (1 - theVehicle_A_payload / 20000) - 0.5 *
    theVehicle_A_aveSpeed / 25) /* adjusted mpg */
    * (theVehicle_A_fuelCapacity * V_vehicleCriteria
    - theVehicle_A_reportedFuelLevel + theVehicle_A_fuelLevel) /* criteria volume */
    / theVehicle_A_aveSpeed /* average speed */
end
else begin
    print ac, ": Error in F_calcFuelUse, type == LAV -> invalid road type"
    to "errorLog.txt"
end

/* Fuel Function for HMMWVs */
else if theVehicle_type is L_HMMWV then begin
    if theVehicle_A_roadType is "paved" then begin
        set V_nextCriteriaTime to ac +
        (10 * (1 - theVehicle_A_payload / 20000) - 1 *
        theVehicle_A_aveSpeed / 45) /* adjusted mpg */
        * (theVehicle_A_fuelCapacity * V_vehicleCriteria
        - theVehicle_A_reportedFuelLevel + theVehicle_A_fuelLevel) /* criteria volume */
        / theVehicle_A_aveSpeed /* average speed */
    end
else if theVehicle_A_roadType is "hard" then begin
set V_nextCriteriaTime to ac +
(8 * (1 - theVehicle_A_payload / 20000) - 1 *
theVehicle_A_aveSpeed / 35) /* adjusted mpg */
* (theVehicle_A_fuelCapacity * V_vehicleCriteria
- theVehicle_A_reportedFuelLevel + theVehicle_A_fuelLevel)/* criteria volume */
/ theVehicle_A_aveSpeed /* average speed */
end
else if theVehicle_A_roadType is "soft" then begin
set V_nextCriteriaTime to ac +
(3 * (1 - theVehicle_A_payload / 20000) - 1 *
theVehicle_A_aveSpeed / 25) /* adjusted mpg */
* (theVehicle_A_fuelCapacity * V_vehicleCriteria
- theVehicle_A_reportedFuelLevel + theVehicle_A_fuelLevel)/* criteria volume */
/ theVehicle_A_aveSpeed /* average speed */
end
else begin
print ac, "- Error in F_calcFuelUse, type == L_HMMWV -> invalid road type" to "errorLog.txt"
end
end
/* Fuel Function for LVSs */
else if theVehicle_type is L_LVS then begin
if theVehicle_A_roadType is "paved" then begin
set V_nextCriteriaTime to ac +
(3 * (1 - theVehicle_A_payload / 20000) - .02 *
theVehicle_A_aveSpeed / 45) /* adjusted mpg */
* (theVehicle_A_fuelCapacity * V_vehicleCriteria
- theVehicle_A_reportedFuelLevel + theVehicle_A_fuelLevel)/* criteria volume */
/ theVehicle_A_aveSpeed /* average speed */
end
else if theVehicle_A_roadType is "hard" then begin
set V_nextCriteriaTime to ac +
(2.5 * (1 - theVehicle_A_payload / 20000) - .02 *
theVehicle_A_aveSpeed / 35) /* adjusted mpg */
* (theVehicle_A_fuelCapacity * V_vehicleCriteria
- theVehicle_A_reportedFuelLevel + theVehicle_A_fuelLevel)/* criteria volume */
/ theVehicle_A_aveSpeed /* average speed */
end
else if theVehicle_A_roadType is "soft" then begin
set V_nextCriteriaTime to ac +
(1 * (1 - theVehicle_A_payload / 20000) - .02 *
theVehicle_A_aveSpeed / 25) /* adjusted mpg */
* (theVehicle_A_fuelCapacity * V_vehicleCriteria
- theVehicle_A_reportedFuelLevel + theVehicle_A_fuelLevel)/* criteria volume */
/ theVehicle_A_aveSpeed /* average speed */
end
else begin
print ac, "- Error in F_calcFuelUse, type == L_LVS -> invalid road type" to "errorLog.txt"
end
end
/* Fuel Function for M1A1s */
else if theVehicle_type is L_M1A1 then begin
if theVehicle_A_roadType is "paved" then begin
set V_nextCriteriaTime to ac +
(.3 * (1 - theVehicle_A_payload / 20000) - .001 *
theVehicle_A_aveSpeed / 45) /* adjusted mpg */
* (theVehicle_A_fuelCapacity * V_vehicleCriteria
- theVehicle_A_reportedFuelLevel + theVehicle_A_fuelLevel)/* criteria volume */
/ theVehicle_A_aveSpeed /* average speed */
end
else if theVehicle A_roadType is "hard" then begin
  set V_nextCriteriaTime to ac +
  \( \frac{(0.25 \times (1 - \text{theVehicle A\_payload} / 20000) - 0.001 \times \text{theVehicle A\_aveSpeed} / 35) \times \text{theVehicle A\_fuelCapacity} \times \text{V\_vehicleCriteria} - \text{theVehicle A\_reportedFuelLevel} + \text{theVehicle A\_fuelLevel}) \times \text{criteria volume}}{\text{theVehicle A\_aveSpeed}} \times \text{average speed} \)
end

else if theVehicle A_roadType is "soft" then begin
  set V_nextCriteriaTime to ac +
  \( \frac{(0.2 \times (1 - \text{theVehicle A\_payload} / 20000) - 0.001 \times \text{theVehicle A\_aveSpeed} / 25) \times \text{theVehicle A\_fuelCapacity} \times \text{V\_vehicleCriteria} - \text{theVehicle A\_reportedFuelLevel} + \text{theVehicle A\_fuelLevel}) \times \text{criteria volume}}{\text{theVehicle A\_aveSpeed}} \times \text{average speed} \)
end

else begin
  print ac, ": Error in F_calcFuelUse, type == L_M1A1 -> invalid road type" to "errorLog.txt"
end

end

/* Fuel Function for MTVRs */
else if theVehicle type is L_MTVR then begin
  if theVehicle A_roadType is "paved" then begin
    set V_nextCriteriaTime to ac +
    \( \frac{(4 \times (1 - \text{theVehicle A\_payload} / 80000) - 0.05 \times \text{theVehicle A\_aveSpeed} / 45) \times \text{theVehicle A\_fuelCapacity} \times \text{V\_vehicleCriteria} - \text{theVehicle A\_reportedFuelLevel} + \text{theVehicle A\_fuelLevel}) \times \text{criteria volume}}{\text{theVehicle A\_aveSpeed}} \times \text{average speed} \)
  end

  else if theVehicle A_roadType is "hard" then begin
    set V_nextCriteriaTime to ac +
    \( \frac{(3.5 \times (1 - \text{theVehicle A\_payload} / 80000) - 0.05 \times \text{theVehicle A\_aveSpeed} / 35) \times \text{theVehicle A\_fuelCapacity} \times \text{V\_vehicleCriteria} - \text{theVehicle A\_reportedFuelLevel} + \text{theVehicle A\_fuelLevel}) \times \text{criteria volume}}{\text{theVehicle A\_aveSpeed}} \times \text{average speed} \)
  end

  else if theVehicle A_roadType is "soft" then begin
    set V_nextCriteriaTime to ac +
    \( \frac{(1 \times (1 - \text{theVehicle A\_payload} / 80000) - 0.05 \times \text{theVehicle A\_aveSpeed} / 25) \times \text{theVehicle A\_fuelCapacity} \times \text{V\_vehicleCriteria} - \text{theVehicle A\_reportedFuelLevel} + \text{theVehicle A\_fuelLevel}) \times \text{criteria volume}}{\text{theVehicle A\_aveSpeed}} \times \text{average speed} \)
  end

  else begin
    print ac, ": Error in F_calcFuelUse, type == L_MTVR -> invalid road type" to "errorLog.txt"
  end

end

else begin
  print ac, ": Error in F_calcFuelUse -> invalid vehicle type" to "errorLog.txt"
end

return V_nextCriteriaTime

end

begin model initialization function
/* default time unit - hours
   default distance unit - miles */

/* set the inter-report time for vehicles */
/* set V_vehReportInterval to 241 hr */

/* set the inter-report time for sixcons */
/* set V_sixconReportInterval to 241 hr */

/* set the vehicle reporting criteria */
/* 25% of capacity */
set V_vehicleCriteria to 1.1

/* set the sixcon reporting criteria */
/* 50 gallons */
set V_sixconCriteria to 1000

/* set the sixcon tank check interval */
/* set V_sixconTankCheckInterval to .25 */
set V_sixconTankCheckInterval to V_sixconReportInterval

/* set the status update time */
set V_statusUpdateInterval to 1 min

/* initialize the status variables */
set C_sixconTankChecks to 0
set C_vehicleReports to 0
set C_sixconReports to 0

/* initialize the packet counters */
set C_vehicleReports to 0
set C_sixconReports to 0
set C_vehicleStartShutReports to 0
set C_movingVehicleReports to 0

/* initialize the capacities, levels, and reported levels */
set V_totalVehicleCapacity to 0
set V_totalSixconCapacity to 0
set V_totalMovingVehicleCapacity to 0
set V_totalVehicleLevel to 0
set V_totalSixconLevel to 0
set V_totalMovingVehicleLevel to 0
set V_totalVehicleReported to 0
set V_totalSixconReported to 0
set V_runningMovingVehicleCapacity to 0
set V_runningMovingVehicleLevel to 0
set V_runningMovingVehicleReported to 0

/* create the control loads */
create 1 load of type L_control to P_vehicleCreation
create 1 load of type L_control to P_statusCheck
create 1 load of type L_control to P_aCoScheduler
create 1 load of type L_control to P_bCoScheduler
create 1 load of type L_control to P_cCoScheduler
create 1 load of type L_control to P_hqScheduler
create 1 load of type L_control to P_artyScheduler

/* open the UpdateLog file */
print "time, totalError, vehicleError, sixconError, patrolError" to "updateLog.csv"
print "time, sixconPercent, sixconPercentReported, vehiclePercent,"
"vehiclePercentReported, totalPercent, totalPercentReported"
to "fuelLevelLog.csv"

return true
/* Create the vehicles */
begin P_vehicleCreation arriving procedure

/* the fuel level at time 0 is known */
set A_lastVehUpdateTime to ac

/* the vehicle is not currently on a patrol or being used on base */
set A_movingVehicle to false

set A_aveSpeed to 0

set A_patrolDistance to 0

set A_roadType to "paved"

/* the vehicle have no payload */
set A_payload to 0

/* Create the AAVs */
/* set the initial attributes */
set load type to L_AAV

/* AAVs have a 400 gallon fuel tank */
set A_fuelCapacity to 400

/* start with a full tank */
set A_fuelLevel to 400

/* the fuel level is known initially */
set A_reportedFuelLevel to A_fuelLevel

/* AAVs do not supply fuel and have no SIXCONS */
set A_sixconCapacity to 0

set A_sixconLevel to 0

set A_sixconReported to 0

/* add the vehicle to B Company */
set A_group to "B_Co"

set A_orderList to OL_bCo

set V_counter to 1

while V_counter <= 15 do begin

/* add this vehicle's fuel to the totals */
set V_totalVehicleCapacity to V_totalVehicleCapacity + A_fuelCapacity

set V_totalVehicleLevel to V_totalVehicleLevel + A_fuelLevel

set V_totalVehicleReported to V_totalVehicleReported + A_reportedFuelLevel

/* Give the AAV an identifying number */
set A_vehicleNumber to V_counter

/* create the vehicle */
clone 1 load to P_createdVehicle

increment V_counter by 1
end

/* Create the HMMWVs */
/* set the initial attributes */
set load type to L_HMMWV

/* HMMWVs have a 25 gallon fuel tank */
set A_fuelCapacity to 25

/* start with a full tank */
set A_fuelLevel to 25

/* the fuel level is known initially */
set A_reportedFuelLevel to A_fuelLevel

/* HMMWVs do not supply fuel and have no SIXCONS */
set A_sixconCapacity to 0

set A_sixconLevel to 0

set A_sixconReported to 0

set V_counter to 1

while V_counter <= 32 do begin

/* add this vehicle's fuel to the totals */
set V_totalVehicleCapacity to V_totalVehicleCapacity + A_fuelCapacity

set V_totalVehicleLevel to V_totalVehicleLevel + A_fuelLevel

set V_totalVehicleReported to V_totalVehicleReported + A_reportedFuelLevel

/* Give the HMMWV an identifying number */
set A_vehicleNumber to V_counter

/* create the vehicle */
clone 1 load to P_createdVehicle

increment V_counter by 1
end
set A_group to "A_Co"
set A_orderList to OL_aCo
end
/* add 10 vehicles to HQ */
else if V_counter <= 16 then begin
set A_group to "HQ"
set A_orderList to OL_hq
end
/* add 8 vehicles to B Company */
else if V_counter <= 24 then begin
set A_group to "B_Co"
set A_orderList to OL_bCo
end
/* add 6 vehicles to C Company */
else if V_counter <= 30 then begin
set A_group to "C_Co"
set A_orderList to OL_cCo
end
/* add the remaining 2 vehicles to the Artillery Battery */
else begin
set A_group to "Arty"
set A_orderList to OL_arty
end
/* create the vehicle */
clone 1 load to P_createdVehicle
increment V_counter by 1
end

/* Create the LAVs */
/* set the initial attributes */
set load type to L_LAV
/* LAVs have a 52 gallon fuel tank */
set A_fuelCapacity to 52
/* start with a full tank */
set A_fuelLevel to 52
/* the fuel level is known initially */
set A_reportedFuelLevel to A_fuelLevel
/* LAVs do not supply fuel and have no SIXCONS */
set A_sixconCapacity to 0
set A_sixconLevel to 0
set A_sixconReported to 0
set V_counter to 1
while V_counter <= 8 do begin
/* add this vehicle's fuel to the totals */
set V_totalVehicleCapacity to V_totalVehicleCapacity + A_fuelCapacity
set V_totalVehicleLevel to V_totalVehicleLevel + A_fuelLevel
set V_totalVehicleReported to V_totalVehicleReported + A_reportedFuelLevel
/* Give the LAV an identifying number */
set A_vehicleNumber to V_counter
/* add 4 vehicles to LAR section 1 */
if V_counter <= 4 then begin
set A_group to "A_Co"
set A_orderList to OL_aCo
end
/* add the other 4 to LAR section 2 */
else begin
set A_group to "B_Co"
set A_orderList to OL_bCo
end
/* create the vehicle */
clone 1 load to P_createdVehicle
increment V_counter by 1
end

/* Create the LVSs */
/* set the initial attributes */
set load type to L_LVS
/* LVSs have a 150 gallon fuel tank */
set A_fuelCapacity to 150
/* start with a full tank */
set A_fuelLevel to 150
/* the fuel level is known initially */
set A_reportedFuelLevel to A_fuelLevel
/* set the capacity of the SIXCONS, each LVS has 3 SIXCONS for a
total capacity of 2700 gallons */
set A_sixconCapacity to 2700
/* the sixcons are initially full */
set A_sixconLevel to 2700
/* the level is initially known */
set A_sixconReported to 2700
set V_counter to 1
while V_counter <= 2 do begin
  /* add this vehicle's fuel to the totals */
  set V_totalVehicleCapacity to V_totalVehicleCapacity + A_fuelCapacity
  set V_totalVehicleLevel to V_totalVehicleLevel + A_fuelLevel
  set V_totalVehicleReported to V_totalVehicleReported + A_reportedFuelLevel
  if A_sixconCapacity > 0 then begin
    set V_totalSixconCapacity to V_totalSixconCapacity + A_sixconCapacity
    set V_totalSixconLevel to V_totalSixconLevel + A_sixconLevel
    set V_totalSixconReported to V_totalSixconReported + A_sixconReported
  end
  /* Give the LVS an identifying number */
  set A_vehicleNumber to V_counter
  /* add the vehicles to B Company */
  set A_group to "B_Co"
  set A_orderList to OL_bCo
  /* create the vehicle */
  clone 1 load to P_createdVehicle
  increment V_counter by 1
end
/* Create the M1A1s */
/* set the initial attributes */
set load type to L_M1A1
/* M1A1s have a 500 gallon tank */
set A_fuelCapacity to 500
/* start with a full tank */
set A_fuelLevel to 500
/* the fuel level is known initially */
set A_reportedFuelLevel to A_fuelLevel
/* M1A1s do not supply fuel and have no SIXCONS */
set A_sixconCapacity to 0
set A_sixconLevel to 0
set A_sixconReported to 0
/* add the vehicle to B Company */
set A_group to "B_Co"
set A_orderList to OL_bCo
set V_counter to 1
while V_counter <= 4 do begin
  /* add this vehicle's fuel to the totals */
  set V_totalVehicleCapacity to V_totalVehicleCapacity + A_fuelCapacity
  set V_totalVehicleLevel to V_totalVehicleLevel + A_fuelLevel
  set V_totalVehicleReported to V_totalVehicleReported + A_reportedFuelLevel
  /* Give the M1A1 an identifying number */
  set A_vehicleNumber to V_counter
  /* create the vehicle */
  clone 1 load to P_createdVehicle
  increment V_counter by 1
end
/* Create the MTVRs */
/* MTVRs have a 78 gallon tank */
set A_fuelCapacity to 78
/* start with a full tank */
set A_fuelLevel to 78
/* the fuel level is known initially */
set A_reportedFuelLevel to A_fuelLevel
set V_counter to 1
while V_counter <= 24 do begin
  /* set the initial attributes */
  set load type to L_MTVR
  /* 6 of the 24 MTVRs provide fuel to other vehicles */
  if V_counter == 1 then begin
    /* This vehicle has 1 SIXCON to provide fuel */
    set A_sixconCapacity to 900
    /* The SIXCON is initially full */
    set A_sixconLevel to 900
    /* the level is initially known */
    set A_sixconReported to 900
    /* This vehicle is part of HQ */
    set A_group to "HQ"
    set A_orderList to OL_hq
  end
  else if V_counter == 2 then begin
    /* This vehicle has 1 SIXCON to provide fuel */
    set A_sixconCapacity to 900
    /* The SIXCON is initially full */
    set A_sixconLevel to 900
    /* the level is initially known */
    set A_sixconReported to 900
    /* This vehicle is part of the Artillery Battery */
    set A_group to "Arty"
    set A_orderList to OL_arty
  end
  else if V_counter == 3 then begin
    /* This vehicle has 1 SIXCON to provide fuel */
    set A_sixconCapacity to 900
    /* The SIXCON is initially full */
    set A_sixconLevel to 900
    /* the level is initially known */
    set A_sixconReported to 900
    /* This vehicle is part of C Company */
    set A_group to "C_Co"
    set A_orderList to OL_cCo
  end
  else if V_counter == 4 then begin
    /* This vehicle has 2 SIXCONs to provide fuel */
    set A_sixconCapacity to 1800
    /* The SIXCON is initially full */
    set A_sixconLevel to 1800
    /* the level is initially known */
    set A_sixconReported to 1800
    /* This vehicle is part of B Company */
    set A_group to "B_Co"
    set A_orderList to OL_bCo
  end
  else if V_counter == 5 then begin
    /* This vehicle has 2 SIXCONs to provide fuel */
    set A_sixconCapacity to 1800
    /* The SIXCON is initially full */
    set A_sixconLevel to 1800
    /* the level is initially known */
    set A_sixconReported to 1800
    /* This vehicle is part of B Company */
    set A_group to "B_Co"
    set A_orderList to OL_bCo
  end
  else if V_counter == 6 then begin
    /* This vehicle has 2 SIXCONs to provide fuel */
    set A_sixconCapacity to 1800
  end
end
/* The SIXCON is initially full */
set A_sixconLevel to 1800
/* the level is initially known */
set A_sixconReported to 1800
/* This vehicle is part of A Company */
set A_group to "A_Co"
set A_orderList to OL_aCo
end
/* The rest of the MTVRs are not fuel suppliers and have no SIXCONs */
else begin
set A_sixconCapacity to 0
set A_sixconLevel to 0
set A_sixconReported to 0
/* add 2 vehicles to HQ */
if V_counter <= 8 then begin
set A_group to "HQ"
set A_orderList to OL_hq
end
/* add 6 vehicles to the Artillery Battery */
else if V_counter <= 14 then begin
set A_group to "Arty"
set A_orderList to OL_arty
end
/* add the other 10 vehicles to A Company */
else begin
set A_group to "A_Co"
set A_orderList to OL_aCo
end
end
/* add this vehicle's fuel to the totals */
set V_totalVehicleCapacity to V_totalVehicleCapacity + A_fuelCapacity
set V_totalVehicleLevel to V_totalVehicleLevel + A_fuelLevel
set V_totalVehicleReported to V_totalVehicleReported + A_reportedFuelLevel
/* if it is a fuel supplier add those numbers to the totals */
if A_sixconCapacity > 0 then begin
set V_totalSixconCapacity to V_totalSixconCapacity + A_sixconCapacity
set V_totalSixconLevel to V_totalSixconLevel + A_sixconLevel
set V_totalSixconReported to V_totalSixconReported + A_sixconReported
end
/* Give the MTVR an identifying number */
set A_vehicleNumber to V_counter
/* create the vehicle */
clone 1 load to P_createdVehicle
increment V_counter by 1
end
/* Tally the fuel level and reported full level data for vehicles. Calculate the percentages and errors. */
call F_fuelTotalsTally()
wait for 1 sec
/* write the vehicle groups to an output file for verification */
print "HQ" to "vehicleGroups.txt"
for each V_load in V_hq do begin
print "t", V_load type, V_load A_vehicleNumber to "vehicleGroups.txt"
if V_load A_sixconCapacity > 0 then begin
print "tSixcon Capacity", V_load A_sixconCapacity to "vehicleGroups.txt"
end
end
print "A Company" to "vehicleGroups.txt"
for each V_load in V_aCo do begin
print "t", V_load type, V_load A_vehicleNumber to "vehicleGroups.txt"
if V_load A_sixconCapacity > 0 then begin

print "Sixcon Capacity", V_load A_sixconCapacity to "vehicleGroups.txt"
end
print "B Company" to "vehicleGroups.txt"
for each V_load in V_bCo do begin
  print "t", V_load type, V_load A_vehicleNumber to "vehicleGroups.txt"
  if V_load A_sixconCapacity > 0 then begin
    print "tSixcon Capacity", V_load A_sixconCapacity to "vehicleGroups.txt"
  end
end
print "C Company" to "vehicleGroups.txt"
for each V_load in V_cCo do begin
  print "t", V_load type, V_load A_vehicleNumber to "vehicleGroups.txt"
  if V_load A_sixconCapacity > 0 then begin
    print "tSixcon Capacity", V_load A_sixconCapacity to "vehicleGroups.txt"
  end
end
print "Artillery Battery" to "vehicleGroups.txt"
for each V_load in V_arty do begin
  print "t", V_load type, V_load A_vehicleNumber to "vehicleGroups.txt"
  if V_load A_sixconCapacity > 0 then begin
    print "tSixcon Capacity", V_load A_sixconCapacity to "vehicleGroups.txt"
  end
end
/* wait until the end of the simulation */
wait for 239.99999 - ac hr
/* calculate and store the mean moving vehicle error */
tabulate (V_runningMovingVehicleReported - V_runningMovingVehicleLevel) /
V_runningMovingVehicleCapacity * 100 in T_meanMovingVehicleError
send to die

/* Put the newly created vehicles on to the vehicle Order List */
begin P_createdVehicle arriving procedure
  set priority to this index + 10
  /* fuel suppliers can have a different reporting period than
  non fuel suppliers. These are set based on global variables
  set during initialization. */
  if A_sixconCapacity > 0 then begin
    set A_lastSixconReportTime to 0
    set A_nextSixconTankCheckTime to V_sixconTankCheckInterval
  end
  /* add it to the appropriate group */
  call F_addToGroup(this)
  /* Record creation in the entityCreation.txt output file */
  print ac, ":", type, A_vehicleNumber,
  "is created and added to the", A_group, "group" to "entityCreation.txt"
  /* Put the vehicle on the vehicle order list */
  wait to be ordered on A_orderList
end

begin F_sendVehicleReport function
  increment C_vehicleReports by 1
  if usage == "moving" then increment C_movingVehicleReports by 1
  else if usage == "startupShutdown" then increment C_vehicleStartShutReports by 1
  else print ac, ": Error in usage in F_sendVehicleReport" to "errorLog.txt"
  /* calculate the amount of fuel used */
  set V_fuelUsed to F_calcFuelUse(theVehicle)
  /* adjust the amount of fuel in the tank */
  set theVehicle A_fuelLevel to theVehicle A_fuelLevel - V_fuelUsed
  set theVehicle A_reportedFuelLevel to theVehicle A_fuelLevel
end
begin F_updateFuelTotals
set V_totalVehicleLevel to V_totalVehicleLevel + theVehicle A_fuelLevel
set V_totalVehicleReported to V_totalVehicleReported + theVehicle A_reportedFuelLevel
if theVehicle A_movingVehicle == true then begin
    set V_totalMovingVehicleLevel to V_totalMovingVehicleLevel + theVehicle A_fuelLevel
    set V_totalMovingVehicleReported to V_totalMovingVehicleReported + theVehicle A_reportedFuelLevel
    set V_totalMovingVehicleCapacity to V_totalMovingVehicleCapacity + theVehicle A_fuelCapacity
    set V_runningMovingVehicleLevel to V_runningMovingVehicleLevel + theVehicle A_fuelLevel
    set V_runningMovingVehicleReported to V_runningMovingVehicleReported + theVehicle A_reportedFuelLevel
    set V_runningMovingVehicleCapacity to V_runningMovingVehicleCapacity + theVehicle A_fuelCapacity
end
if (theVehicle A_sixconCapacity > 0 and theVehicle A_sixconReported >= theVehicle A_sixconLevel) then begin
    set V_totalSixconLevel to V_totalSixconLevel + theVehicle A_sixconLevel
    set V_totalSixconReported to V_totalSixconReported + theVehicle A_sixconReported
    set V_totalSixconCapacity to V_totalSixconCapacity + theVehicle A_sixconCapacity
end
return true
end
begin F_fuelTotalsTally
/* tally the vehicle fuel data */
set V_totalFuelCapacity to V_totalVehicleCapacity + V_totalSixconCapacity
set V_totalFuelLevel to V_totalVehicleLevel + V_totalSixconLevel
set V_totalFuelReported to V_totalVehicleReported + V_totalSixconReported

/* change capacities that equal 0 to some other value to avoid NaN results */
if V_totalMovingVehicleCapacity == 0 then set V_totalMovingVehicleCapacity to 1

set V_vehicleError to (V_totalVehicleReported - V_totalVehicleLevel) / V_totalVehicleCapacity * 100
set V_movingVehicleError to (V_totalMovingVehicleReported - V_totalMovingVehicleLevel) / V_totalMovingVehicleCapacity * 100
set V_sixconError to (V_totalSixconReported - V_totalSixconLevel) / V_totalSixconCapacity * 100
set V_totalError to (V_totalFuelReported - V_totalFuelLevel) / V_totalFuelCapacity * 100

tabulate V_vehicleError in T_vehicleError
tabulate V_movingVehicleError in T_movingVehicleError
begin F_pumpFuel function
	/* determine the amount of fuel needed */
	set V_fuelUsed to theVehicle A_fuelCapacity - theVehicle A_fuelLevel
	/* choose a fuel supplier within the vehicle's group that
has a sufficient amount of fuel to dispense */
	print ac, ",", theVehicle A_group, theVehicle type, theVehicle A_vehicleNumber, 
"needs fuel" to "pumpLog.txt"

	/* find the fuel suppliers in the group */
	remove all from V_tempLoadList

to each V_load in F_getGroup(theVehicle A_group) do begin
	if V_load A_sixconCapacity > 0 insert V_load into V_tempLoadList
end
	/* choose 1 to get fuel from */
	choose a load from among V_tempLoadList
	whose A_sixconLevel >= V_fuelUsed
	save choice as V_fuelSupplier

	/* if none of the fuel suppliers in the group have sufficient
fuel, print an error message */
	if V_fuelSupplier == null then begin
		print "No fuel available" to "pumpLog.txt"
		print ac, ": fuel shortage in", theVehicle A_group, 
		"with vehicle", theVehicle type, theVehicle A_vehicleNumber
	
to "errorLog.txt"
end
else begin
	/* take the fuel from the sixcon */
	set V_fuelSupplier A_sixconLevel to
	V_fuelSupplier A_sixconLevel - V_fuelUsed
	print ",", V_fuelUsed, "pumped from", V_fuelSupplier type, 
V_fuelSupplier A_vehicleNumber, ",", 
V_fuelSupplier A_sixconReported, " - true:", 
V_fuelSupplier A_sixconLevel to "pumpLog.txt"
end

	/* add the fuel to the vehicle */
	set theVehicle A_fuelLevel to theVehicle A_fuelCapacity
	return true
end

/* there is no LoadListPtr attribute available, so we need to store
the vehicle's group as a string and use functions to access the
true load list */
begin F_addToGroup function
	if theVehicle A_group == "HQ" then begin
		insert theVehicle into V_hq at end
end
else if theVehicle A_group == "A_Co" then begin
		insert theVehicle into V_aCo at end
end
else if theVehicle A_group == "B_Co" then begin
		insert theVehicle into V_bCo at end
end
else if theVehicle A_group == "C_Co" then begin
		insert theVehicle into V_cCo at end
end
else if theVehicle A_group == "Arty" then begin

insert theVehicle into V_arty at end

else begin
    print ac, ": Error in F_addToGroup function",
    "group name can't be resolved to a load list" to "errorLog.txt"
end

return true
end

/* Same issue as above. Need a way to resolve the string attribute to an actual load list. Note: this function doesn't return a pointer to the list. It returns a new list with the same loads on it. If you try to add or remove items from the return value, the true lists will not be altered. */

begin F_getGroup function
    if group == "A_Co" then return V_aCo
else if group == "B_Co" then return V_bCo
else if group == "C_Co" then return V_cCo
else if group == "Arty" then return V_arty
else if group == "HQ" then return V_hq
else begin
    print ac, ": Error in F_getGroup function",
    "group name can't be resolved to a load list" to "errorLog.txt"
    return null
end
end

begin F_setNextEventTime function
    if theVehicle A_group == "A_Co" then begin
        set theVehicle A_nextEventTime to V_aCoNextEventTime
    end
else if theVehicle A_group == "B_Co" then begin
    set theVehicle A_nextEventTime to V_bCoNextEventTime
end
else if theVehicle A_group == "C_Co" then begin
    set theVehicle A_nextEventTime to V_cCoNextEventTime
end
else if theVehicle A_group == "Arty" then begin
    set theVehicle A_nextEventTime to V_artyNextEventTime
end
else if theVehicle A_group == "HQ" then begin
    set theVehicle A_nextEventTime to V_hqNextEventTime
end
else begin
    print ac, ": Error in F_setNextEventTime function",
    "group name didn't match any group" to "errorLog.txt"
end

return true
end

begin F_setPatrolParameters function
    if theVehicle A_group == "A_Co" then begin
        set theVehicle A_returnTime to V_aCoReturnTime - .0001
        set theVehicle A_roadType to V_aCoRoadType
        set theVehicle A_aveSpeed to V_aCoAverageSpeed
        set theVehicle A_legType to V_aCoLegType
    end
else if theVehicle A_group == "B_Co" then begin
    set theVehicle A_returnTime to V_bCoReturnTime - .0001
    set theVehicle A_roadType to V_bCoRoadType
    set theVehicle A_aveSpeed to V_bCoAverageSpeed
    set theVehicle A_legType to V_bCoLegType
end
else if theVehicle A_group == "C_Co" then begin
    set theVehicle A_returnTime to V_cCoReturnTime - .0001
    set theVehicle A_roadType to V_cCoRoadType
    set theVehicle A_aveSpeed to V_cCoAverageSpeed
    set theVehicle A_legType to V_cCoLegType
end
else begin
    print ac, ": Error in F_setPatrolParameters function",
    "group name didn't match any group" to "errorLog.txt"
end

return true
end
set theVehicle A_roadType to V_cCoRoadType
set theVehicle A_aveSpeed to V_cCoAverageSpeed
set theVehicle A_legType to V_cCoLegType
end
else if theVehicle A_group == "Arty" then begin
set theVehicle A_returnTime to V_artyReturnTime - .0001
set theVehicle A_roadType to V_artyRoadType
set theVehicle A_aveSpeed to V_artyAverageSpeed
set theVehicle A_legType to V_artyLegType
end
else if theVehicle A_group == "HQ" then begin
set theVehicle A_returnTime to V_hqReturnTime - .0001
set theVehicle A_roadType to V_hqRoadType
set theVehicle A_aveSpeed to V_hqAverageSpeed
set theVehicle A_legType to V_hqLegType
end
else begin
print ac, ": Error in F_setPatrolParameters function",
"group name didn't match any group" to "errorLog.txt"
end
return true
end
begin F_setIdleFuelParameters function
if theVehicle A_group == "A_Co" then begin
set theVehicle A_endIdleTime to V_aCoNextUnitMoveTime - .0001
end
else if theVehicle A_group == "B_Co" then begin
set theVehicle A_endIdleTime to V_bCoNextUnitMoveTime - .0001
end
else if theVehicle A_group == "C_Co" then begin
set theVehicle A_endIdleTime to V_cCoNextUnitMoveTime - .0001
end
else if theVehicle A_group == "Arty" then begin
set theVehicle A_endIdleTime to V_artyNextUnitMoveTime - .0001
end
else if theVehicle A_group == "HQ" then begin
set theVehicle A_endIdleTime to V_hqNextUnitMoveTime - .0001
end
else begin
print ac, ": Error in F_setPatrolParameters function",
"group name didn't match any group" to "errorLog.txt"
end
return true
end
begin F_fuelResupply function
for each V_load in theVehicles do begin
if V_load A_sixconCapacity > 0 begin
print ac, ":", V_load A_group, V_load type,
V_load A_vehicleNumber, "is resupplied with",
V_load A_sixconCapacity - V_load A_sixconLevel
end
set V_load A_sixconLevel to V_load A_sixconCapacity
end
return true
end
begin F_setNextVehicleReportTime function
set V_nextConditionTime to F_calcNextConditionTime(theVehicle)
if V_nextConditionTime < (theVehicle A_lastVehReportTime
+ V_vehReportInterval) then begin
set theVehicle A_nextVehReportTime to V_nextConditionTime
end
return true
end
91
else begin
  set A_nextVehReportTime to (A_lastVehReportTime + V_vehReportInterval)
end

return true
end

/* fuel supply vehicles will be sending packets even when they 
aren't being driven */
begin P_idleFuelSupplier arriving procedure
  call F_setIdleFuelParameters(this)
  while A_endIdleTime >= A_nextSixconTankCheckTime do begin
    wait for A_nextSixconTankCheckTime - ac
    /* check the tank level */
    increment C_sixconTankChecks by (A_sixconCapacity / 900)
    print ac, type, A_vehicleNumber, "checks tank - ", A_sixconCapacity / 900 to "tankCheckLog.txt"
    /* send a time or condition based report, if necessary */
    if ac >= A_lastSixconReportTime + V_sixconReportInterval
    /* or A_sixconLevel <= A_sixconReported - 
      V_sixconCriteria * A_sixconCapacity / 900 
      or A_sixconLevel > A_sixconReported */ then begin
      /* send the sixcon reports */
      call F_sendSixconReport(this)
    end
    set A_nextSixconTankCheckTime to ac + V_sixconTankCheckInterval
  end
  wait for A_endIdleTime - ac
  wait to be ordered on A_orderList
end

begin P_patrol arriving procedure
  /* set the patrol parameters */
  call F_setPatrolParameters(this)
  /* Assume that the vehicle has a full tank because all 
  vehicles are refueling after any patrol or unit 
  movement. No refueling is necessary before departure */
  /* send startup report */
  set A_lastVehUpdateTime to ac
  call F_sendVehicleReport(this "startupShutdown")
  /* The vehicle departs with the patrol */
  set A_movingVehicle to true
  increment C_movingVehicles by 1
  insert this into V_movingVehicles at end
  print ac, ":	", A_group, type, A_vehicleNumber, "departs on Patrol with", 
  A_fuelLevel, "fuel" to "movementLog.txt"
  /* Determine the next report time. This sets the A_nextVehReportTime attribute */
  call F_setNextVehicleReportTime(this)
  /* while the convoy is out, send reports at the specified interval */
  while A_returnTime > A_nextVehReportTime do begin
    /* wait until the next report time */
    wait for (A_nextVehReportTime - ac)
    /* send a report now */
    call F_sendVehicleReport(this "moving")
    print ac, ":t":A_group, type, A_vehicleNumber, "on Patrol", 
    "sends fuel status report - has", A_fuelLevel, "remaining" 
    to "movementLog.txt"
/* Determine the next report time. This sets the A_nextVehReportTime attribute */
call F_setNextVehicleReportTime(this)
end

/* drive the last portion of the patrol */
wait for A_returnTime - ac

/* send shutdown report */
call F_sendVehicleReport(this "startupShutdown")
/* the vehicle is no longer on a patrol */
print ac, ":		", A_group, type, A_vehicleNumber, "completes movement with", A_fuelLevel, "gallons remaining" to "movementLog.txt"
remove this load from V_movingVehicles
set A_movingVehicle to false
decrement C_movingVehicles by 1
set A_aveSpeed to 0
set A_patrolDistance to 0

/* the vehicles can't all fill up at once, they do so over a 20 minute period. */
wait for rn stream1 u 10,10 min
/* get fuel */
call F_pumpFuel(this)
/* send startup report */
call F_sendVehicleReport(this "startupShutdown")

/* the vehicle drives to wherever it parks - is assumed to be negligible and left out of the simulation */

/* the vehicle sends a shutdown report */
call F_sendVehicleReport(this "startupShutdown")
print ac, ":		", A_group, type, A_vehicleNumber,
"refills its tank and shuts down" to "movementLog.txt"

wait to be ordered on A_orderList
end

begin P_unitMovementStart arriving procedure
set A_remainingReportTime to 0

/* send startup report */
set A_lastVehUpdateTime to ac
call F_sendVehicleReport(this "startupShutdown")

/* The vehicle departs with the convoy */
insert this load into V_movingVehicles at end
set A_movingVehicle to true
increment C_movingVehicles by 1
print ac, ":		", A_group, type, A_vehicleNumber, "departs with", A_fuelLevel, "fuel" to "movementLog.txt"
send to P_unitMovement
end

begin P_unitMovement arriving procedure
/* set the patrol parameters */
call F_setPatrolParameters(this)

/* Determine when the next report will be sent */
call F_setNextVehicleReportTime(this)

/* while the convoy is out, send reports at the specified interval */
while A_returnTime > A_nextVehReportTime do begin
if A_sixconCapacity > 0 then begin
while A_nextVehReportTime >= A_nextSixconTankCheckTime do begin
/* wait until the next tank check time */
wait for A_nextSixconTankCheckTime - ac
/* check the tank */
end
end
/* Determin the next report time. This sets the A_nextVehReportTime attribute */
call F_setNextVehicleReportTime(this)
end
increment C_sixconTankChecks by A_sixconCapacity / 900
print ac, type, A_vehicleNumber, "checks tank - ", A_sixconCapacity / 900 to "tankCheckLog.txt"

/* send report if necessary */
if ac >= A_lastSixconReportTime + V_sixconReportInterval
/* or A_sixconLevel <= A_sixconReported - 
V_sixconCriteria * A_sixconCapacity / 900 
or A_sixconLevel > A_sixconReported */ then begin
/* send sixcon reports */
call F_sendSixconReport(this)
end
end
set A_nextSixconTankCheckTime to ac + V_sixconTankCheckInterval

end

/* wait until the next report time */
wait for A_nextVehReportTime - ac
/* send a report now */
call F_sendVehicleReport(this "moving")

print ac, ":t", A_group, type, A_vehicleNumber, 
"sends fuel status report - has", A_fuelLevel, "remaining" 
to "movementLog.txt"

/* Determine the next report time. This sets the A_nextVehReportTime attribute */
call F_setNextVehicleReportTime(this)
end

if A_sixconCapacity > 0 then begin
while A_returnTime >= A_nextSixconTankCheckTime do begin
/* wait until the next tank check time */
wait for A_nextSixconTankCheckTime - ac
/* check the tank */
increment C_sixconTankChecks by A_sixconCapacity / 900
print ac, type, A_vehicleNumber, "checks tank - ", A_sixconCapacity / 900 to "tankCheckLog.txt"
/* send report if necessary */
if ac >= A_lastSixconReportTime + V_sixconReportInterval
or A_sixconLevel <= A_sixconReported - 
V_sixconCriteria * A_sixconCapacity / 900 
or A_sixconLevel > A_sixconReported then begin
/* send sixcon reports and count the packets */
call F_sendSixconReport(this)
end
end
set A_nextSixconTankCheckTime to ac + V_sixconTankCheckInterval
end
end

/* drive the last portion of the patrol */
wait for A_returnTime - ac
/* calculate the amount of fuel used */
set V_fuelUsed to F_calcFuelUse(this)
/* adjust the amount of fuel in the tank */
set A_fuelLevel to A_fuelLevel - V_fuelUsed
set A_lastVehUpdateTime to ac

if A_legType == "normal" then begin
print ac, ":t", A_group, type, A_vehicleNumber, "finishes leg with", 
A_fuelLevel, "fuel remaining" to "movementLog.txt"
set A_remainingReportTime to A_nextVehReportTime - ac

wait to be ordered on A_orderList
end

else if A_legType == "final" then begin
/* the vehicle is no longer on a patrol */
print ac, ":t", A_group, type, A_vehicleNumber, "completes movement with", 
A_fuelLevel, "gallons remaining" to "movementLog.txt"
remove this load from V_movingVehicles

set A_movingVehicle to false
decrement C_movingVehicles by 1
set A_aveSpeed to 0
set A_patrolDistance to 0

if A_sixconCapacity > 0 then begin
   /* the vehicle refills its fuel tank */
   /* send shutdown report */
   call F_sendVehicleReport(this "startupShutdown")
   /* get fuel */
   call F_pumpFuel(this)
   /* send startup report */
   call F_sendVehicleReport(this "startupShutdown")
   /* move to parking area and shutdown */
   /* send shutdown report */
   call F_sendVehicleReport(this "startupShutdown")
end

else begin
   /* the vehicle refills its fuel tank */
   /* send shutdown report */
   call F_sendVehicleReport(this "startupShutdown")
   /* the vehicles can't all fill up at once, they do so over a
   20 minute period. */
   wait for rn stream1 u 10,10 min
   /* get fuel */
   call F_pumpFuel(this)
   /* send startup report */
   call F_sendVehicleReport(this "startupShutdown")
end

/* the vehicle drives to where ever it parks - is assumed to be
negligible and left out of the simulation */
/* the vehicle sends a shutdown report */
call F_sendVehicleReport(this "startupShutdown")

print ac, ":		", A_group, type, A_vehicleNumber, "refills its tank and shuts down"
to "movementLog.txt"

if A_sixconCapacity > 0 then send to P_idleFuelSupplier
   wait to be ordered on A_orderList
end

else begin
   print "Error in patrolLogic.m, illegal A_legType used." to "errorLog.txt"
end

end

begin P_statusCheck arriving procedure
   /* make sure that the status update is the last thing done */
   set priority to 200

   while 1 = 1 do begin
      wait for V_statusUpdateInterval

      /* update fuel level of the vehicles on patrol */
      for each V_load in V_movingVehicles do begin
         set V_fuelUsed to F_calcFuelUse(V_load)
         set V_load A_fuelLevel to V_load A_fuelLevel - V_fuelUsed
         set V_load A_lastVehUpdateTime to ac
      end

      /* Get the true and reported status */
      set V_totalVehicleReported to 0
      set V_totalVehicleLevel to 0
      set V_totalMovingVehicleReported to 0
      set V_totalMovingVehicleLevel to 0
set V_totalMovingVehicleCapacity to 0
set V_totalSixconLevel to 0
set V_totalSixconReported to 0
set V_totalSixconCapacity to 0

/* get the fuel values from each group */
for each V_load in V_hq do begin
    call F_updateFuelTotals(V_load)
end
for each V_load in V_aCo do begin
    call F_updateFuelTotals(V_load)
end
for each V_load in V_bCo do begin
    call F_updateFuelTotals(V_load)
end
for each V_load in V_cCo do begin
    call F_updateFuelTotals(V_load)
end
for each V_load in V_arty do begin
    call F_updateFuelTotals(V_load)
end
end

begin P_aCoScheduler arriving procedure
set priority to 1
wait for 1 sec
set V_aCoNextEventTime to 5 hr
set V_aCoNextUnitMoveTime to 5 hr

/* initially, the fuel suppliers are idle, but sending messages */
order all loads satisfying A_sixconCapacity > 0 from OL_aCo to P_idleFuelSupplier

wait for V_aCoNextEventTime - ac
/* A Co moves at Day 1 0500 (5) */
set V_aCoRoadType to "paved"
set V_aCoAverageSpeed to 40
set V_aCoReturnTime to 8 hr
set V_aCoNextEventTime to 9 hr
set V_aCoNextUnitMoveTime to 9 hr
set V_aCoLegType to "final"
order all loads from OL_aCo to P_unitMovementStart

wait for V_aCoNextEventTime - ac
/* A Co moves at Day 1 0900 (9) */
set V_aCoRoadType to "paved"
set V_aCoAverageSpeed to 40
set V_aCoReturnTime to 12 hr
set V_aCoNextEventTime to 12 hr
set V_aCoNextUnitMoveTime to 12 hr
set V_aCoLegType to "normal"
order all loads from OL_aCo to P_unitMovementStart

wait for V_aCoNextEventTime - ac

/* A Co continues moving at Day 1 1200 (12) */
set V_aCoRoadType to "soft"
set V_aCoAverageSpeed to 15
set V_aCoReturnTime to 13 hr
set V_aCoNextEventTime to 14 hr
set V_aCoNextUnitMoveTime to 14 hr
set V_aCoLegType to "final"
order all loads from OL_aCo to P_unitMovement

wait for V_aCoNextEventTime - ac

/* A Co moves at Day 1 1400 (14) */
set V_aCoRoadType to "hard"
set V_aCoAverageSpeed to 15
set V_aCoReturnTime to 17 hr
set V_aCoNextEventTime to 17 hr
set V_aCoNextUnitMoveTime to 17 hr
set V_aCoLegType to "normal"
order all loads from OL_aCo to P_unitMovementStart

wait for V_aCoNextEventTime - ac

/* A Co continues moving at Day 1 1700 (17) */
set V_aCoRoadType to "hard"
set V_aCoAverageSpeed to 10
set V_aCoReturnTime to 18 hr
set V_aCoNextEventTime to 30 hr
set V_aCoNextUnitMoveTime to 129 hr /* Day 6 0900 */
set V_aCoLegType to "final"
order all loads from OL_aCo to P_unitMovement

wait for V_aCoNextEventTime - ac

/* A Co sends out a patrol Day 2 0600 (30) */
set V_aCoRoadType to "hard"
set V_aCoAverageSpeed to 25
set V_aCoReturnTime to 35 hr
set V_aCoNextEventTime to 34 hr
order 4 loads satisfying type == L_LAV from OL_aCo to P_patrol

wait for V_aCoNextEventTime - ac

/* A Co sends out a patrol Day 2 1000 (34) */
set V_aCoRoadType to "hard"
set V_aCoAverageSpeed to 20
set V_aCoReturnTime to 38 hr
set V_aCoNextEventTime to 39 hr
order 4 loads satisfying type == L_HMMWV from OL_aCo to P_patrol

wait for V_aCoNextEventTime - ac

/* A Co receives a resupply of fuel Day 2 1500 (39) */
call F_fuelResupply(V_aCo)

/* A Co sends out a patrol Day 2 1500 (39) */
set V_aCoRoadType to "hard"
set V_aCoAverageSpeed to 20
set V_aCoReturnTime to 41 hr
set V_aCoNextEventTime to 52 hr
order 2 loads satisfying type == L_HMMWV from OL_aCo to P_patrol
order 2 loads satisfying type == L_MTVR and A_sixconCapacity = 0 from OL_aCo to P_patrol

wait for V_aCoNextEventTime - ac

/* A Co sends out a patrol Day 3 0400 (52) */
set V_aCoRoadType to "soft"
set V_aCoAverageSpeed to 15
set V_aCoReturnTime to 55 hr
set V_aCoNextEventTime to 59 hr
order 4 loads satisfying type == L_HMMWV from OL_aCo to P_patrol
order 2 loads satisfying type == L_MTVR and A_sixconCapacity = 0 from OL_aCo to P_patrol

wait for V_aCoNextEventTime - ac
/* A Co sends out a patrol Day 3 1100 (59) */
set V_aCoRoadType to "hard"
set V_aCoAverageSpeed to 25
set V_aCoReturnTime to 65 hr
set V_aCoNextEventTime to 77 hr
order 4 loads satisfying type == L_LAV from OL_aCo to P_patrol

wait for V_aCoNextEventTime - ac
/* A Co sends out a patrol Day 4 0500 (77) */
set V_aCoRoadType to "hard"
set V_aCoAverageSpeed to 30
set V_aCoReturnTime to 82 hr
set V_aCoNextEventTime to 81 hr
order 4 loads satisfying type == L_LAV from OL_aCo to P_patrol

wait for V_aCoNextEventTime - ac
/* A Co sends out a patrol Day 4 0900 (81) */
set V_aCoRoadType to "hard"
set V_aCoAverageSpeed to 30
set V_aCoReturnTime to 103 hr
set V_aCoNextEventTime to 109 hr
order 4 loads satisfying type == L_HMMWV from OL_aCo to P_patrol

wait for V_aCoNextEventTime - ac
/* A Co sends out a patrol Day 5 0700 (103) */
set V_aCoRoadType to "paved"
set V_aCoAverageSpeed to 30
set V_aCoReturnTime to 113 hr
set V_aCoNextEventTime to 129 hr
order 4 loads satisfying type == L_LAV from OL_aCo to P_patrol

wait for V_aCoNextEventTime - ac
/* A Co sends out a patrol Day 5 1300 (109) */
set V_aCoRoadType to "paved"
set V_aCoAverageSpeed to 30
set V_aCoReturnTime to 129 hr
set V_aCoNextEventTime to 129 hr
set V_aCoNextUnitMoveTime to 133 hr
set V_aCoLegType to "normal"
order all loads from OL_aCo to P_unitMovementStart

wait for V_aCoNextEventTime - ac
/* A Co moves at Day 6 0900 (129) */
set V_aCoRoadType to "paved"
set V_aCoAverageSpeed to 35
set V_aCoReturnTime to 133 hr
set V_aCoNextEventTime to 133 hr
set V_aCoNextUnitMoveTime to 133 hr
set V_aCoLegType to "normal"
order all loads from OL_aCo to P_unitMovementStart

wait for V_aCoNextEventTime - ac
/* A Co continues moving at Day 6 1300 (133) */
set V_aCoRoadType to "hard"
set V_aCoAverageSpeed to 20
set V_aCoReturnTime to 136 hr
set V_aCoNextEventTime to 148 hr
set V_aCoNextUnitMoveTime to 240.1 hr
set V_aCoLegType to "final"
order all loads from OL_aCo to P_unitMovement

wait for V_aCoNextEventTime - ac
/* A Co sends out a patrol Day 7 0400 (148) */
set V_aCoRoadType to "soft"
set V_aCoAverageSpeed to 15
set V_aCoReturnTime to 151 hr
set V_aCoNextEventTime to 150 hr
order 4 loads satisfying type == L_HMMWV from OL_aCo
to P_patrol
order 2 loads satisfying type == L_MTVR and A_sixconCapacity = 0
from OL_aCo to P_patrol

wait for V_aCoNextEventTime - ac
/* A Co receives a resupply of fuel Day 7 0600 (150) */
call F_fuelResupply(V_aCo)
set V_aCoNextEventTime to 155 hr

wait for V_aCoNextEventTime - ac
/* A Co sends out a patrol Day 7 1100 (155) */
set V_aCoRoadType to "hard"
set V_aCoAverageSpeed to 25
set V_aCoReturnTime to 161 hr
set V_aCoNextEventTime to 173 hr
order 4 loads satisfying type == L_LAV from OL_aCo
to P_patrol

wait for V_aCoNextEventTime - ac
/* A Co sends out a patrol Day 8 0500 (173) */
set V_aCoRoadType to "hard"
set V_aCoAverageSpeed to 30
set V_aCoReturnTime to 177 hr
set V_aCoNextEventTime to 177 hr
order 4 loads satisfying type == L_LAV from OL_aCo
to P_patrol

wait for V_aCoNextEventTime - ac
/* A Co sends out a patrol Day 8 0900 (177) */
set V_aCoRoadType to "hard"
set V_aCoAverageSpeed to 25
set V_aCoReturnTime to 198 hr
set V_aCoNextEventTime to 198 hr
order 4 loads satisfying type == L_HMMWV from OL_aCo
to P_patrol

wait for V_aCoNextEventTime - ac
/* A Co sends out a patrol Day 9 0600 (198) */
set V_aCoRoadType to "hard"
set V_aCoAverageSpeed to 25
set V_aCoReturnTime to 203 hr
set V_aCoNextEventTime to 202 hr
order 4 loads satisfying type == L_LAV from OL_aCo
to P_patrol

wait for V_aCoNextEventTime - ac
/* A Co sends out a patrol Day 9 1000 (202) */
set V_aCoRoadType to "hard"
set V_aCoAverageSpeed to 20
set V_aCoReturnTime to 206 hr
set V_aCoNextEventTime to 207 hr
order 4 loads satisfying type == L_HMMWV from OL_aCo
to P_patrol

wait for V_aCoNextEventTime - ac
/* A Co sends out a patrol Day 9 1500 (207) */
set V_aCoRoadType to "hard"
set V_aCoAverageSpeed to 20
set V_aCoReturnTime to 209 hr
set V_aCoNextEventTime to 220 hr
order 2 loads satisfying type == L_HMMWV from OL_aCo
to P_patrol
order 2 loads satisfying type == L_MTVR and A_sixconCapacity = 0
from OL_aCo to P_patrol
wait for V_aCoNextEventTime - ac

/* A Co sends out a patrol Day 10 0400 (220) */
set V_aCoRoadType to "soft"
set V_aCoAverageSpeed to 15
set V_aCoReturnTime to 223 hr
set V_aCoNextEventTime to 227 hr
order 4 loads satisfying type == L_HMMWV from OL_aCo
to P_patrol
order 2 loads satisfying type == L_MTVR and A_sixconCapacity = 0
from OL_aCo to P_patrol
wait for V_aCoNextEventTime - ac

/* A Co sends out a patrol Day 10 1100 (227) */
set V_aCoRoadType to "hard"
set V_aCoAverageSpeed to 25
set V_aCoReturnTime to 233 hr
set V_aCoNextEventTime to 240 hr
order 4 loads satisfying type == L_LAV from OL_aCo
to P_patrol

end

begin P_bCoScheduler arriving procedure
set priority to 2
wait for 1 sec
set V_bCoNextEventTime to 5 hr
set V_bCoNextUnitMoveTime to 5 hr

/* initially, the fuel suppliers are idle,
but sending messages */
order all loads satisfying A_sixconCapacity > 0
from OL_bCo to P_idleFuelSupplier

wait for V_bCoNextEventTime - ac
/* B Co moves at Day 1 0500 (5) */
set V_bCoRoadType to "paved"
set V_bCoAverageSpeed to 40
set V_bCoReturnTime to 8 hr
set V_bCoNextEventTime to 9 hr
set V_bCoNextUnitMoveTime to 9 hr
set V_bCoLegType to "final"
order all loads from OL_bCo to P_unitMovementStart

wait for V_bCoNextEventTime - ac
/* B Co moves at Day 1 0900 (9) */
set V_bCoRoadType to "paved"
set V_bCoAverageSpeed to 25
set V_bCoReturnTime to 11 hr
set V_bCoNextEventTime to 11 hr
set V_bCoNextUnitMoveTime to 11 hr
set V_bCoLegType to "normal"
order all loads from OL_bCo to P_unitMovementStart

wait for V_bCoNextEventTime - ac
/* B Co moves at Day 1 1100 (11) */
set V_bCoRoadType to "hard"
set V_bCoAverageSpeed to 20
set V_bCoReturnTime to 13 hr
set V_bCoNextEventTime to 14 hr
set V_bCoNextUnitMoveTime to 14 hr
set V_bCoLegType to "final"
order all loads from OL_bCo to P_unitMovement

wait for V_bCoNextEventTime - ac
/* B Co moves at Day 1 1400 (14) */
set V_bCoRoadType to "hard"
set V_bCoAverageSpeed to 15
set V_bCoReturnTime to 16 hr
set V_bCoNextEventTime to 30 hr
set V_bCoNextUnitMoveTime to 130 hr
set V_bCoLegType to "final"
order all loads from OL_bCo to P_unitMovementStart

wait for V_bCoNextEventTime - ac
/*/ B Co sends out a patrol Day 2 0600 (30) */
set V_bCoRoadType to "hard"
set V_bCoAverageSpeed to 20
set V_bCoReturnTime to 34 hr
set V_bCoNextEventTime to 32 hr
order 4 loads satisfying type == L_LAV from OL_bCo to P_patrol
order 2 loads satisfying type == L_M1A1 from OL_bCo to P_patrol

wait for V_bCoNextEventTime - ac
/*/ B Co receives a resupply of fuel Day 2 0800 (32) */
call F_fuelResupply(V_bCo)
/*/ B Co sends out a patrol Day 2 0800 (32) */
set V_bCoRoadType to "soft"
set V_bCoAverageSpeed to 15
set V_bCoReturnTime to 35 hr
set V_bCoNextEventTime to 38 hr
order 6 loads satisfying type == L_AAV from OL_bCo to P_patrol
order 6 loads satisfying type == L_M1A1 from OL_bCo to P_patrol

wait for V_bCoNextEventTime - ac
/*/ B Co sends out a patrol Day 2 1400 (38) */
set V_bCoRoadType to "soft"
set V_bCoAverageSpeed to 20
set V_bCoReturnTime to 41 hr
set V_bCoNextEventTime to 55 hr
order 6 loads satisfying type == L_AAV from OL_bCo to P_patrol
order 2 loads satisfying type == L_M1A1 from OL_bCo to P_patrol

wait for V_bCoNextEventTime - ac
/*/ B Co sends out a patrol Day 3 0700 (55) */
set V_bCoRoadType to "soft"
set V_bCoAverageSpeed to 15
set V_bCoReturnTime to 59 hr
set V_bCoNextEventTime to 57 hr
order 4 loads satisfying type == L_AAV from OL_bCo to P_patrol

wait for V_bCoNextEventTime - ac
/*/ B Co sends out a patrol Day 3 0900 (57) */
set V_bCoRoadType to "hard"
set V_bCoAverageSpeed to 20
set V_bCoReturnTime to 63 hr
set V_bCoNextEventTime to 61 hr
order 4 loads satisfying type == L_LAV from OL_bCo to P_patrol

wait for V_bCoNextEventTime - ac
/*/ B Co sends out a patrol Day 3 1300 (61) */
set V_bCoRoadType to "hard"
set V_bCoAverageSpeed to 20
set V_bCoReturnTime to 65 hr
set V_bCoNextEventTime to 78 hr
order 5 loads satisfying type == L_AAV from OL_bCo
to P_patrol

wait for V_bCoNextEventTime - ac
/* B Co sends out a patrol Day 4 0600 (78) */
set V_bCoRoadType to "hard"
set V_bCoAverageSpeed to 20
set V_bCoReturnTime to 83 hr
set V_bCoNextEventTime to 82 hr
order 4 loads satisfying type == L_LAV from OL_bCo
to P_patrol

wait for V_bCoNextEventTime - ac
/* B Co sends out a patrol Day 4 1000 (82) */
set V_bCoRoadType to "paved"
set V_bCoAverageSpeed to 20
set V_bCoReturnTime to 88 hr
set V_bCoNextEventTime to 102 hr
order 5 loads satisfying type == L_HMMWV from OL_bCo
to P_patrol

wait for V_bCoNextEventTime - ac
/* B Co sends out a patrol Day 5 0600 (102) */
set V_bCoRoadType to "paved"
set V_bCoAverageSpeed to 15
set V_bCoReturnTime to 105 hr
set V_bCoNextEventTime to 106 hr
order 4 loads satisfying type == L_HMMWV from OL_bCo
to P_patrol

wait for V_bCoNextEventTime - ac
/* B Co sends out a patrol Day 5 1000 (106) */
set V_bCoRoadType to "hard"
set V_bCoAverageSpeed to 25
set V_bCoReturnTime to 130 hr
set V_bCoNextEventTime to 133 hr
order 4 loads satisfying type == L_HMMWV from OL_bCo
to P_patrol

wait for V_bCoNextEventTime - ac
/* B Co moves at Day 6 1000 (130) */
set V_bCoRoadType to "hard"
set V_bCoAverageSpeed to 25
set V_bCoReturnTime to 133 hr
set V_bCoNextEventTime to 133 hr
set V_bCoNextUnitMoveTime to 240.1 hr
set V_bCoLegType to "final"
order all loads from OL_bCo to P_unitMovementStart

wait for V_bCoNextEventTime - ac
/* B Co moves at Day 6 1300 (133) */
set V_bCoRoadType to "soft"
set V_bCoAverageSpeed to 10
set V_bCoReturnTime to 135 hr
set V_bCoNextEventTime to 151 hr
set V_bCoNextUnitMoveTime to 240.1 hr
set V_bCoLegType to "final"
order all loads from OL_bCo to P_unitMovement

wait for V_bCoNextEventTime - ac
/* B Co sends out a patrol Day 7 0700 (151) */
set V_bCoRoadType to "soft"
set V_bCoAverageSpeed to 15
set V_bCoReturnTime to 155 hr
set V_bCoNextEventTime to 153 hr
order 4 loads satisfying type == L_AAV from OL_bCo to P_patrol

wait for V_bCoNextEventTime - ac

/* B Co receives a resupply of fuel Day 7 0900 (153) */
call F_fuelResupply(V_bCo)

/* B Co sends out a patrol Day 7 0900 (153) */
set V_bCoRoadType to "hard"
set V_bCoAverageSpeed to 20
set V_bCoReturnTime to 159 hr
set V_bCoNextEventTime to 157 hr

order 4 loads satisfying type == L_LAV from OL_bCo to P_patrol

wait for V_bCoNextEventTime - ac

/* B Co sends out a patrol Day 7 1300 (157) */
set V_bCoRoadType to "hard"
set V_bCoAverageSpeed to 20
set V_bCoReturnTime to 161 hr
set V_bCoNextEventTime to 174 hr

order 5 loads satisfying type == L_AAV from OL_bCo to P_patrol

wait for V_bCoNextEventTime - ac

/* B Co sends out a patrol Day 8 0600 (174) */
set V_bCoRoadType to "hard"
set V_bCoAverageSpeed to 20
set V_bCoReturnTime to 179 hr
set V_bCoNextEventTime to 178 hr

order 4 loads satisfying type == L_LAV from OL_bCo to P_patrol

wait for V_bCoNextEventTime - ac

/* B Co sends out a patrol Day 8 1000 (178) */
set V_bCoRoadType to "paved"
set V_bCoAverageSpeed to 20
set V_bCoReturnTime to 184 hr
set V_bCoNextEventTime to 178 hr

order 6 loads satisfying type == L_HMMWV from OL_bCo to P_patrol

wait for V_bCoNextEventTime - ac

/* B Co sends out a patrol Day 8 2100 (189) */
set V_bCoRoadType to "soft"
set V_bCoAverageSpeed to 10
set V_bCoReturnTime to 193 hr
set V_bCoNextEventTime to 198 hr

order 6 loads satisfying type == L_AAV from OL_bCo to P_patrol

wait for V_bCoNextEventTime - ac

/* B Co sends out a patrol Day 9 0600 (198) */
set V_bCoRoadType to "hard"
set V_bCoAverageSpeed to 20
set V_bCoReturnTime to 202 hr
set V_bCoNextEventTime to 199 hr

order 4 loads satisfying type == L_LAV from OL_bCo to P_patrol

wait for V_bCoNextEventTime - ac

/* B Co sends out a patrol Day 9 0700 (199) */
set V_bCoRoadType to "soft"
set V_bCoAverageSpeed to 15
set V_bCoReturnTime to 203 hr
set V_bCoNextEventTime to 206 hr

order 6 loads satisfying type == L_AAV from OL_bCo to P_patrol

order 2 loads satisfying type == L_M1A1 from OL_bCo
to P_patrol

wait for V_bCoNextEventTime - ac
/* B Co sends out a patrol Day 9 1400 (206) */
set V_bCoRoadType to "hard"
set V_bCoAverageSpeed to 20
set V_bCoReturnTime to 211 hr
set V_bCoNextEventTime to 223 hr
order 6 loads satisfying type == L_AAV from OL_bCo
to P_patrol
order 2 loads satisfying type == L_M1A1 from OL_bCo
to P_patrol

wait for V_bCoNextEventTime - ac
/* B Co sends out a patrol Day 10 0700 (223) */
set V_bCoRoadType to "soft"
set V_bCoAverageSpeed to 15
set V_bCoReturnTime to 227 hr
set V_bCoNextEventTime to 225 hr
order 4 loads satisfying type == L_AAV from OL_bCo
to P_patrol

wait for V_bCoNextEventTime - ac
/* B Co sends out a patrol Day 10 0900 (225) */
set V_bCoRoadType to "hard"
set V_bCoAverageSpeed to 20
set V_bCoReturnTime to 231 hr
set V_bCoNextEventTime to 233 hr
order 4 loads satisfying type == L_LAV from OL_bCo
to P_patrol

wait for V_bCoNextEventTime - ac
/* B Co sends out a patrol Day 10 0900 (229) */
set V_bCoRoadType to "hard"
set V_bCoAverageSpeed to 20
set V_bCoReturnTime to 233 hr
set V_bCoNextEventTime to 240 hr
order 5 loads satisfying type == L_AAV from OL_bCo
to P_patrol

end

begin P_cCoScheduler arriving procedure
set priority to 3
wait for 1 sec
set V_cCoNextEventTime to 5 hr
set V_cCoNextUnitMoveTime to 5 hr

/* initially, the fuel suppliers are idle,
but sending messages */
order all loads satisfying A_sixconCapacity > 0
from OL_cCo to P_idleFuelSupplier

wait for V_cCoNextEventTime - ac
/* C Co moves at Day 1 0500 (5) */
set V_cCoRoadType to "paved"
set V_cCoAverageSpeed to 40
set V_cCoReturnTime to 8 hr
set V_cCoNextEventTime to 9 hr
set V_cCoNextUnitMoveTime to 9 hr
set V_cCoLegType to "final"
order all loads from OL_cCo to P_unitMovementStart

wait for V_cCoNextEventTime - ac
/* C Co moves at Day 1 0900 (9) */
set V_cCoRoadType to "paved"
set V_cCoAverageSpeed to 25
set V_cCoReturnTime to 12 hr
set V_cCoNextEventTime to 34 hr
set V_cCoNextUnitMoveTime to 105 hr
set V_cCoLegType to "final"
order all loads from OL_cCo to P_unitMovementStart

wait for V_cCoNextEventTime - ac
/* C Co sends out a patrol Day 2 1000 (34) */
set V_cCoRoadType to "paved"
set V_cCoAverageSpeed to 30
set V_cCoReturnTime to 37 hr
set V_cCoNextEventTime to 41 hr
order 4 loads satisfying type == L_HMMWV from OL_cCo to P_patrol

wait for V_cCoNextEventTime - ac
/* C Co sends out a patrol Day 2 1700 (41) */
set V_cCoRoadType to "hard"
set V_cCoAverageSpeed to 20
set V_cCoReturnTime to 44 hr
set V_cCoNextEventTime to 57 hr
order 4 loads satisfying type == L_HMMWV from OL_cCo to P_patrol

wait for V_cCoNextEventTime - ac
/* C Co sends out a patrol Day 3 0900 (57) */
set V_cCoRoadType to "hard"
set V_cCoAverageSpeed to 20
set V_cCoReturnTime to 63 hr
set V_cCoNextEventTime to 63 hr
order 4 loads satisfying type == L_HMMWV from OL_cCo to P_patrol

wait for V_bCoNextEventTime - ac
/* C Co receives a resupply of fuel Day 3 1500 (63) */
call F_fuelResupply(V_cCo)
set V_cCoNextEventTime to 79

wait for V_cCoNextEventTime - ac
/* C Co sends out a patrol Day 4 0700 (79) */
set V_cCoRoadType to "paved"
set V_cCoAverageSpeed to 25
set V_cCoReturnTime to 85 hr
set V_cCoNextEventTime to 105 hr
order 4 loads satisfying type == L_HMMWV from OL_cCo to P_patrol

wait for V_cCoNextEventTime - ac
/* C Co moves at Day 5 0900 (105) */
set V_cCoRoadType to "paved"
set V_cCoAverageSpeed to 25
set V_cCoReturnTime to 109 hr
set V_cCoNextEventTime to 126 hr
set V_cCoNextUnitMoveTime to 240.1 hr
set V_cCoLegType to "final"
order all loads from OL_cCo to P_unitMovementStart

wait for V_cCoNextEventTime - ac
/* C Co sends out a patrol Day 6 0600 (126) */
set V_cCoRoadType to "paved"
set V_cCoAverageSpeed to 30
set V_cCoReturnTime to 129 hr
set V_cCoNextEventTime to 153 hr
order 4 loads satisfying type == L_HMMWV from OL_cCo to P_patrol

wait for V_cCoNextEventTime - ac
/* C Co sends out a patrol Day 7 0900 (153) */
set V_cCoRoadType to "hard"
set V_cCoAverageSpeed to 20
set V_cCoReturnTime to 159 hr
set V_cCoNextEventTime to 175 hr
order 5 loads satisfying type == L_HMMWV from OL_cCo
to P_patrol

wait for V_cCoNextEventTime - ac
/* C Co sends out a patrol Day 8 0700 (175) */
set V_cCoRoadType to "paved"
set V_cCoAverageSpeed to 25
set V_cCoReturnTime to 181 hr
set V_cCoNextEventTime to 187 hr
order 4 loads satisfying type == L_HMMWV from OL_cCo
to P_patrol

wait for V_cCoNextEventTime - ac
/* C Co sends out a patrol Day 9 1000 (202) */
set V_cCoRoadType to "paved"
set V_cCoAverageSpeed to 30
set V_cCoReturnTime to 205 hr
set V_cCoNextEventTime to 209 hr
order 4 loads satisfying type == L_HMMWV from OL_cCo
to P_patrol

wait for V_cCoNextEventTime - ac
/* C Co sends out a patrol Day 9 1700 (209) */
set V_cCoRoadType to "hard"
set V_cCoAverageSpeed to 20
set V_cCoReturnTime to 212 hr
set V_cCoNextEventTime to 225 hr
order 4 loads satisfying type == L_HMMWV from OL_cCo
to P_patrol

wait for V_cCoNextEventTime - ac
/* C Co sends out a patrol Day 10 0900 (225) */
set V_cCoRoadType to "hard"
set V_cCoAverageSpeed to 20
set V_cCoReturnTime to 231 hr
set V_cCoNextEventTime to 240 hr
order 4 loads satisfying type == L_HMMWV from OL_cCo
to P_patrol

end

begin P_hqScheduler arriving procedure
set priority to 4
wait for 1 sec
set V_hqNextEventTime to 5 hr
set V_hqNextUnitMoveTime to 5 hr
/* Initially, the fuel suppliers are idle, 
but sending messages */
order all loads satisfying A_sixconCapacity > 0
from OL_hq to P_idleFuelSupplier

wait for V_hqNextEventTime - ac
/* HQ moves at Day 1 0500 (5) */
set V_hqRoadType to "paved"
set V_hqAverageSpeed to 40
set V_hqReturnTime to 8 hr
set V_hqNextEventTime to 9 hr
set V_hqNextUnitMoveTime to 9 hr
set V_hqLegType to "final"
order all loads from OL_hq to P_unitMovementStart

wait for V_hqNextEventTime - ac
/* HQ moves at Day 1 0900 (9) */
set V_hqRoadType to "paved"
set V_hqAverageSpeed to 30
set V_hqReturnTime to 11 hr
set V_hqNextEventTime to 54 hr
set V_hqNextUnitMoveTime to 104 hr
set V_hqLegType to "final"
order all loads from OL_hq to P_unitMovementStart
wait for V_hqNextEventTime - ac
/* HQ sends out a patrol Day 3 0600 (54) */
set V_hqRoadType to "paved"
set V_hqAverageSpeed to 25
set V_hqReturnTime to 59 hr
set V_hqNextEventTime to 62 hr
order 6 loads satisfying type == L_HMMWV from OL_hq to P_patrol
wait for V_hqNextEventTime - ac
/* HQ receives a resupply of fuel Day 3 1400 (62) */
call F_fuelResupply(V_hq)
/* HQ sends out a patrol Day 3 1400 (62) */
set V_hqRoadType to "soft"
set V_hqAverageSpeed to 15
set V_hqReturnTime to 65 hr
set V_hqNextEventTime to 87 hr
order 4 loads satisfying type == L_HMMWV from OL_hq to P_patrol
wait for V_hqNextEventTime - ac
/* HQ moves at Day 5 0800 (104) */
set V_hqRoadType to "hard"
set V_hqAverageSpeed to 30
set V_hqReturnTime to 107 hr
set V_hqNextEventTime to 128 hr
set V_hqNextUnitMoveTime to 240.1 hr
set V_hqLegType to "final"
order all loads from OL_hq to P_unitMovementStart
wait for V_hqNextEventTime - ac
/* HQ sends out a patrol Day 6 0800 (128) */
set V_hqRoadType to "hard"
set V_hqAverageSpeed to 20
set V_hqReturnTime to 134 hr
set V_hqNextEventTime to 150 hr
order 6 loads satisfying type == L_HMMWV from OL_hq to P_patrol
wait for V_hqNextEventTime - ac
/* HQ sends out a patrol Day 7 0600 (150) */
set V_hqRoadType to "paved"
set V_hqAverageSpeed to 25
set V_hqReturnTime to 155 hr
set V_hqNextEventTime to 160 hr
order 6 loads satisfying type == L_HMMWV from OL_hq to P_patrol
wait for V_hqNextEventTime - ac
/* HQ sends out a patrol Day 7 1600 (160) */
set V_hqRoadType to "soft"
set V_hqAverageSpeed to 15
set V_hqReturnTime to 163 hr
set V_hqNextEventTime to 183 hr
order 4 loads satisfying type == L_HMMWV from OL_hq to P_patrol

wait for V_hqNextEventTime - ac
/* HQ sends out a patrol Day 8 1500 (183) */
set V_hqRoadType to "hard"
set V_hqAverageSpeed to 15
set V_hqReturnTime to 187 hr
set V_hqNextEventTime to 222 hr
order 6 loads satisfying type == L_HMMWV from OL_hq to P_patrol

wait for V_hqNextEventTime - ac
/* HQ sends out a patrol Day 10 0600 (222) */
set V_hqRoadType to "paved"
set V_hqAverageSpeed to 25
set V_hqReturnTime to 227 hr
set V_hqNextEventTime to 230 hr
order 6 loads satisfying type == L_HMMWV from OL_hq to P_patrol

wait for V_hqNextEventTime - ac
/* HQ sends out a patrol Day 10 1400 (230) */
set V_hqRoadType to "soft"
set V_hqAverageSpeed to 15
set V_hqReturnTime to 233 hr
set V_hqNextEventTime to 240 hr
order 4 loads satisfying type == L_HMMWV from OL_hq to P_patrol

end

begin P_artyScheduler arriving procedure
  set priority to 5
  wait for 1 sec
  set V_artyNextEventTime to 5 hr
  set V_artyNextUnitMoveTime to 5 hr

  /* initially, the fuel suppliers are idle, 
  but sending messages */
  order all loads satisfying A_sixconCapacity > 0
  from OL_arty to P_idleFuelSupplier

  wait for V_artyNextEventTime - ac
  /* Arty moves at Day 1 0500 (5) */
  set V_artyRoadType to "paved"
  set V_artyAverageSpeed to 40
  set V_artyReturnTime to 8 hr
  set V_artyNextEventTime to 9 hr
  set V_artyNextUnitMoveTime to 9 hr
  set V_artyLegType to "final"
  order all loads from OL_arty to P_unitMovementStart

  wait for V_artyNextEventTime - ac
  /* Arty moves at Day 1 0900 (9) */
  set V_artyRoadType to "paved"
  set V_artyAverageSpeed to 30
  set V_artyReturnTime to 11 hr
  set V_artyNextEventTime to 33 hr
  set V_artyNextUnitMoveTime to 104 hr
  set V_artyLegType to "final"
  order all loads from OL_arty to P_unitMovementStart

  wait for V_artyNextEventTime - ac
  /* Arty sends out a patrol Day 2 0900 (33) */
  set V_artyRoadType to "hard"
  set V_artyAverageSpeed to 20
  set V_artyReturnTime to 37 hr
  set V_artyNextEventTime to 62 hr
order 2 loads satisfying type == L_HMMWV from OL_arty to P_patrol
order 2 loads satisfying type == L_MTVR and A_sixconCapacity = 0 from OL_arty to P_patrol

wait for V_artyNextEventTime - ac
/* Arty receives a resupply of fuel Day 3 1400 (62) */
call F_fuelResupply(V_arty)
set V_artyNextEventTime to 78 hr

wait for V_artyNextEventTime - ac
/* Arty sends out a patrol Day 4 0600 (78) */
set V_artyRoadType to "hard"
set V_artyAverageSpeed to 20
set V_artyReturnTime to 82 hr
set V_artyNextEventTime to 104 hr
order 2 loads satisfying type == L_HMMWV from OL_arty to P_patrol
order 2 loads satisfying type == L_MTVR and A_sixconCapacity = 0 from OL_arty to P_patrol

wait for V_artyNextEventTime - ac
/* Arty moves at Day 5 0800 (104) */
set V_artyRoadType to "hard"
set V_artyAverageSpeed to 20
set V_artyReturnTime to 108 hr
set V_artyNextEventTime to 174 hr
set V_artyNextUnitMoveTime to 240.1 hr
set V_artyLegType to "final"
order all loads from OL_arty to P_unitMovementStart

wait for V_artyNextEventTime - ac
/* Arty sends out a patrol Day 8 0600 (174) */
set V_artyRoadType to "hard"
set V_artyAverageSpeed to 20
set V_artyReturnTime to 177 hr
set V_artyNextEventTime to 201 hr
order 2 loads satisfying type == L_HMMWV from OL_arty to P_patrol
order 2 loads satisfying type == L_MTVR and A_sixconCapacity = 0 from OL_arty to P_patrol

wait for V_artyNextEventTime - ac
/* Arty sends out a patrol Day 9 0900 (201) */
set V_artyRoadType to "hard"
set V_artyAverageSpeed to 20
set V_artyReturnTime to 205 hr
set V_artyNextEventTime to 240 hr
order 2 loads satisfying type == L_HMMWV from OL_arty to P_patrol
order 2 loads satisfying type == L_MTVR and A_sixconCapacity = 0 from OL_arty to P_patrol

end
Appendix C: Simulation Run Results

C.1 Unscripted Time Based Results

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<thead>
<tr>
<th>Patrol Rate</th>
<th>Sixcon Report Interval</th>
<th>Vehicle Report Interval</th>
<th>Max Sixcon Error</th>
<th>Max Vehicle Error</th>
<th>Mean Sixcon Error</th>
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- **C Company**
  - HMMWV 30mph for 3hr 20mph
  - HMMWV paved for 3hr
  - HMMWV 90mi hard
  - HMMWV 60mi
  - MTVR
  - HQ

- **A Company**
  - LAV 25mph
  - LAV hard
  - LAV 6hr
  - LAV 150mi
  - HMMWV
  - HMMWV 15mph
  - HMMWV soft
  - HMMWV 6hr
  - HMMWV 90mi
  - MTVR
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- **Artillery**
  - HMMWV
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- **MTVR**
  - 4hr
  - 80mi

- **Day 3**
  - 20mph hard
  - 4hr
  - 80mi
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**Notes:**

- **HMMWV:** High-Mobility Multipurpose Wheeled Vehicle
- **MTVR:** Medium Tactical Vehicle Replacement
- **LAV:** Light Armored Vehicle
- **25mph, 30mph:** Speed in miles per hour
- **paved, hard:** Road conditions
- **6hr, 60mi:** Duration and distance

---

**Artillery:**

- 20mph
- hard
- 6hr
- 60mi
| Hour | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
| B Company | LAV | LAV | LAV | LAV | LAV | AAV | AAV | AAV | AAV | AAV | AAV | AAV | AAV | AAV | AAV | AAV | HMMWV | HMMWV | HMMWV | HMMWV | HMMWV | HMMWV | HMMWV |
| | 25mph | hard | 4hr | 100mi |
| | 30mph | soft | 4hr | 60mi |
| C Company | HMMWV | HMMWV | HMMWV | HMMWV | HMMWV | HMMWV | HMMWV | HMMWV | M1A1 | M1A1 | M1A1 | M1A1 | M1A1 | M1A1 | MTVR | MTVR | MTVR | MTVR | MTVR | MTVR |
| | 25mph | refuel | paved | 4hr | 100mi |
| | 30mph | hard | 3hr | 60mi |
| HQ | HMMWV | HMMWV | HMMWV | HMMWV | HMMWV | HMMWV | HMMWV | HMMWV | MTVR | MTVR | MTVR | MTVR | MTVR | MTVR | MTVR | MTVR |
| | 25mph | refuel | hard | 4hr | 80mi |
| Artillery | HMMWV | HMMWV | MTVR | MTVR | MTVR | MTVR | MTVR | MTVR | MTVR | MTVR | MTVR | MTVR | MTVR | MTVR | MTVR | MTVR | MTVR | MTVR | MTVR | MTVR | MTVR | MTVR | MTVR |
| | 25mph | refuel | hard | 4hr | 80mi |
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- **C Company:** 30mph, paved, 3hr, 90mi
- **HQ:** 30mph, hard, 1hr, 120mi
- **Artillery:** 30mph, soft, 3hr, 90mi
- **A Company:** 25mph, hard, 1hr, 150mi

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**Resupply:**
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#### C Company
- HMMWV 25mph
- HMMWV paved
- HMMWV 6hr 15mph
- HMMWV 150mi hard
- HMMWV 3hr
- HMMWV 45mi
- MTVR
- HQ

#### A Company
- LAV 25mph
- LAV hard
- LAV 5hr
- LAV 125mi
- HMMWV 20mph
- HMMWV hard
- HMMWV 4hr
- HMMWV 80mi
- MTVR 2hr
- MTVR 40mi
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24hr
period

5hr
12hrs

24hr

6hr
12hrs

1.5hr
soft
7mi
45mi
Appendix E: Vehicle and SIXCON Information

E.1 Vehicle and SIXCON Information

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Name</th>
<th>Quantity in Simulations</th>
<th>Fuel Capacity (gallons)</th>
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<td>Amphibious Assault Vehicle</td>
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<td>LAV</td>
<td>Light Armored Vehicle</td>
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<td>Logistics Vehicle System</td>
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<td>M1 Abrams Tank</td>
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E.2 Fuel Economy Calculations

The fuel economy for the simulated vehicles was calculated from Equation E-1 using the data in Table E-1 and Table E-2. This equation is meant to approximate the vehicles’ fuel economy under varying operation conditions (road type, speed, and payload). For this study, payload was always assumed to be zero.

**Equation E-1: Fuel Economy Equation**

\[
\text{Fuel Economy (mpg)} = \text{Rated Fuel Economy} \times \left(1 - \frac{\text{Payload}}{\text{Vehicle Payload Factor}}\right) \\
- \text{Vehicle Speed Factor} \times \frac{\text{Speed}}{\text{Road Type Factor}}
\]
### Table E-1: Road Type Factors

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### Table E-2: Vehicle Specific Factors

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Bibliography


Rabah, M. Y., & Mahmassani, H. S. (2002). *Impact of electronic commerce on logistics operations: a focus on Vendor Managed Inventory (VMI) strategies*. Report Number SWUTC/02/16727-1, University of Texas at Austin, Center for Transportation Research, Austin, TX.


