Right Sizing Navy Fire & Emergency Services

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1 Problem Description

The team was presented with the following customer needs:

What is the right level of physical Fire and Emergency Services (F&ES) resources required by a Navy installation in a fiscally constrained environment?
If we had to apportion resources across multiple installations, how could we do so and "level" risk across the supported installations?
For a given budgeting level for the enterprise, what is the right mix of capabilities at each installation?

Currently the F&ES does not have an analytical method to determine the risk level and minimize the risk to cope with a reduced budget. A mathematical simulation model would provide a repeatable and systematic approach for explaining possible effects of change such as reducing future resources. The model will alter the mix of F&ES capabilities across 70 naval base installations. These capabilities include the number of stations, trucks, engines, ambulances, and crew. Effectiveness of resources, F&ES guidelines, budgeting constraints, and the costs associated with individual resources were considered. Initially the model took a high-level approach to assessing the risk by examining the effect of multiple simultaneous events. After consulting the sponsor the direction was later modified to a more low-level simulation model to meet the customer requirements. The model incorporates all events F&ES personnel encounter including traffic accidents, fires, and health emergencies. The output of the model became effectiveness, which represents how fast the resources can reach the event and handle the multiple events properly.

The sponsor has requested a loss function and defined loss as a function of FE&S assets and base installation features. The loss equation is L = F (A , I).

1.1 Background and Motivation

Fred Woodaman is a Principal Analyst with Innovative Decisions, who sponsors the F&ES project. Mr. Woodaman has created a cost model called Fire and Emergency Service Program Objectives Memorandum (FESPOM). FESPOM calculates resources required while meeting policy requirements. This cost model was provided and can be merged with the Fire and Emergency Services Effectiveness Baseline Evaluator (FESEBLE) product. FESPOM can also assist with the analysis estimation risk, analysis on dollar loss, and lives loss per event at desired place. The event locations and fire stations can be configured based on the resources and distance location for more accurate simulation results. Mr. Woodaman provided data including equipment resources, personnel, and maps for over 70 naval installations.

The project motivation is best explained with an article from Public Radio International's The World, dated January 10, 2011. The article stated:

Secretary of Defense has set a goal of saving $150 billion from the Pentagon budget over the next five years. $35 billion of those proposed savings would come from the US Navy.
The Navy planned to meet its budget mostly by trimming personnel.
The Navy sees its identity as being, understandably enough, in sailing ships, so if by eliminating some staff organizations that they don't think they need, they can get more ships out on the ocean doing what the Navy is there to do.
The unit prepares and predicts but former unit director says it's difficult to know what ship, plane, or weapon will work best in the future. It's very hard to look out much further than five to 10 years. This leaves Secretary Gates in a tough position. The military has to maximize its ability to fight and minimize its expenses. There are a lot of different opinions about how to do that. In the end though, Congress gets to decide the military budget. And all good lawmakers know that if a ship or weapon is built in their district, well then, of course, that ship or weapon is the one the Navy simply cannot do without.

A simulation model tool can assist with estimating the risk level based on an allocated budget. The model provides the Navy with a way to properly allocate resources given budget cuts. Resources need to be reduced with minimal damage to the entire fire and emergency base services.

1.2 Problem Statement

Develop a mathematical model of the expected loss at an installation given an application of F&ES resources.

1.2.1 Existing products

A cost estimation model tool has been created by Mr. Woodaman, FESPOM, and calculates the required resource (e.g. number of vehicles) to meet the demand. Demand is based on acceptable risk incorporating the total cost for the equipment and personnel. The cost is calculated from the fleet size and suitable administrative support. FESPOM projects the required equipment, personnel, and the cost for each resource.

1.2.2 Product being developed

A mathematical model will be developed calculating the expected loss at an installation given an application of F&ES resources. The focus of the research and study is placed on measuring resource effectiveness and event response. The variables include event location and type, resource type and availability, simultaneous events, specialty-trained personnel versus regular trained staff, and dispatch technology advancement. F&ES dispatch systems get triggered by an alarm. The dispatch system first determines whether a false event occurred, then the event location is recognized. The firefighting station at the shortest distance is found and proper resources are sent out to the event based on the event type and size.

The naval base data was studied and an attempt to generate a mathematical model to simulate events was made. Eventually the model was narrowed down to one station. The mathematical model can be generated and configurable for any station.

1.3 Objective

Generate a risk analysis model for estimation dollars and lives lost per event.

1.4 Stakeholders

The main stakeholders are the users, client and customers. The client of the FESEBLE product would be Mr. Woodaman of the project. The customer would be the Commander, Navy Installations Command (CNIC) Headquarters Program Director. Users would be the staff of the director.

1.5 Definition

V-model life cycle was used during the project. However, due to modifications in the direction of the project and time constraints, use cases for the requirements were derived after the simulation was produced. During verification, the simulation was updated to meet requirements found during the use case analysis. Figure 2 displays the v-model process.

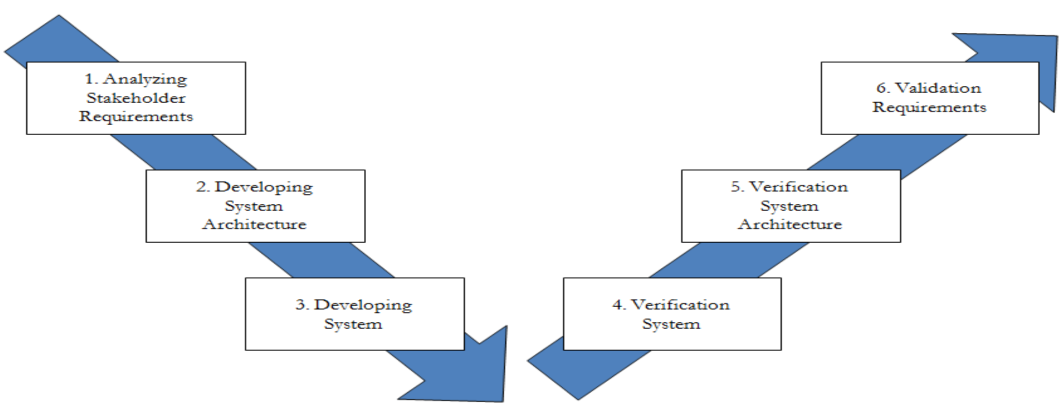

Figure 1

2 Requirements

The context diagram is displayed under figure 3 and shows the adjacent systems explaining the existing process.

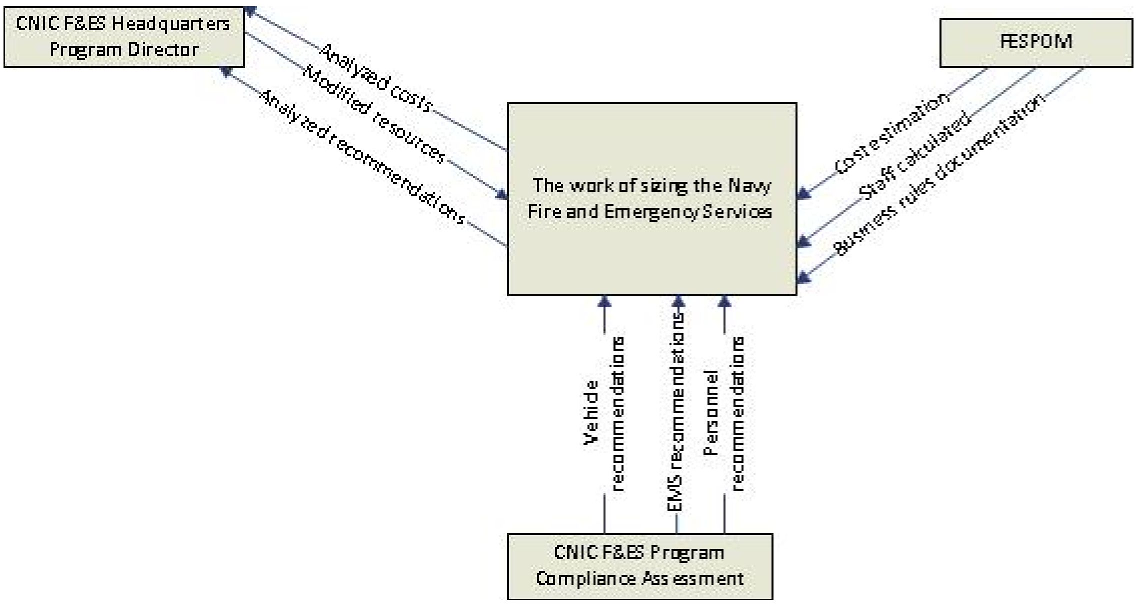

Figure 2

The event list contains the events that affect the system with the input triggering an event and the resulting output. Table 2 contains the event list produced using the context diagram.

Table 1

Event name	Input and Output
1. PCA submits vehicle recommendations	Vehicle recommendations (in)
2. PCA submits personnel recommendations	Personnel recommendations (in)
3. PCA submits EMS recommendations	EMS recommendations (in)
4. FESPOM provides business rules documentation	Business rules document (in)
5. FESPOM calculates staff required	Staff calculation (in)
6. FESPOM estimates cost	Cost estimation (in)
7. Program Director analyzes cost	Cost analysis (out)
8. Program Director analyzes recommendations	Program Compliance Assessment (out)
9. Program Director modifies resources	Change resources (in)

The use case diagram is represented in figure 4. The actors are shown and the diagram makes up the functionality of the product. The requirements will be derived from these functions.

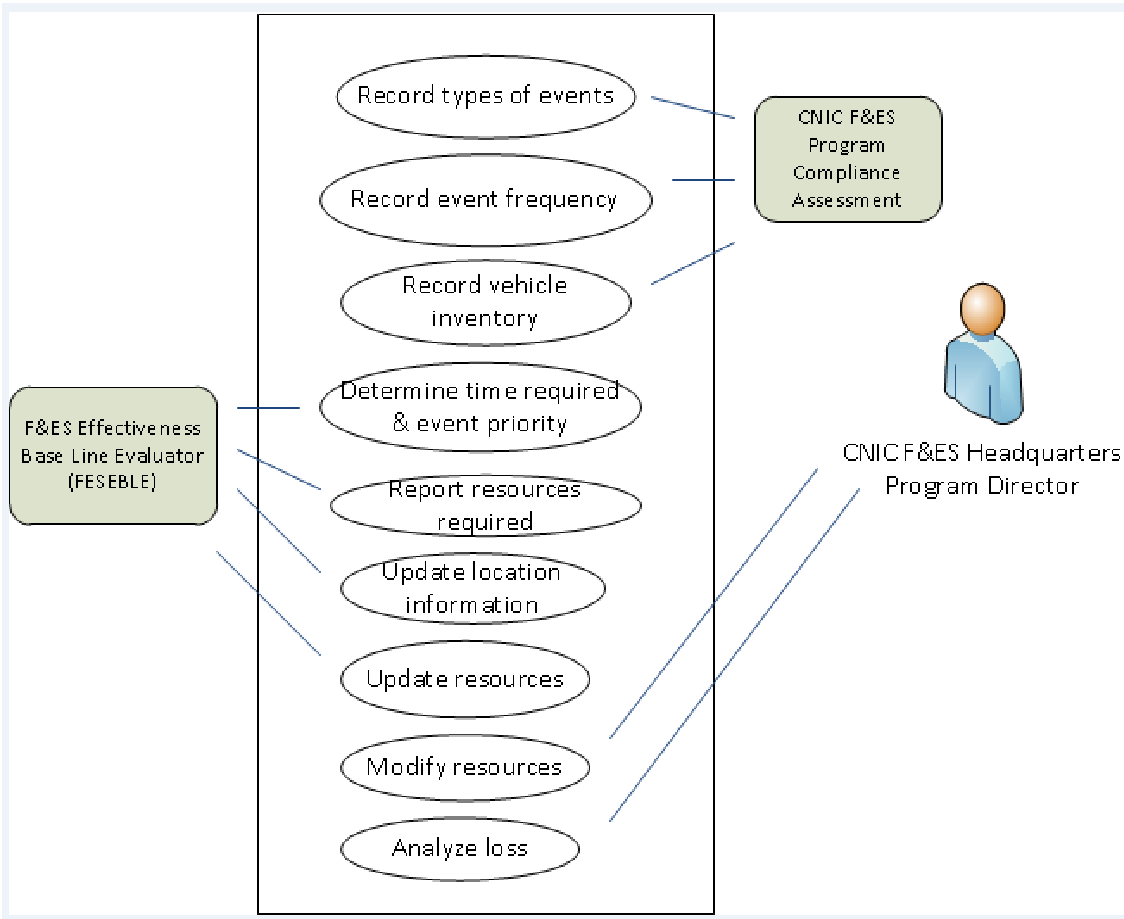

Figure 3

Figure 5 below represents the role of requirements in the development cycle.

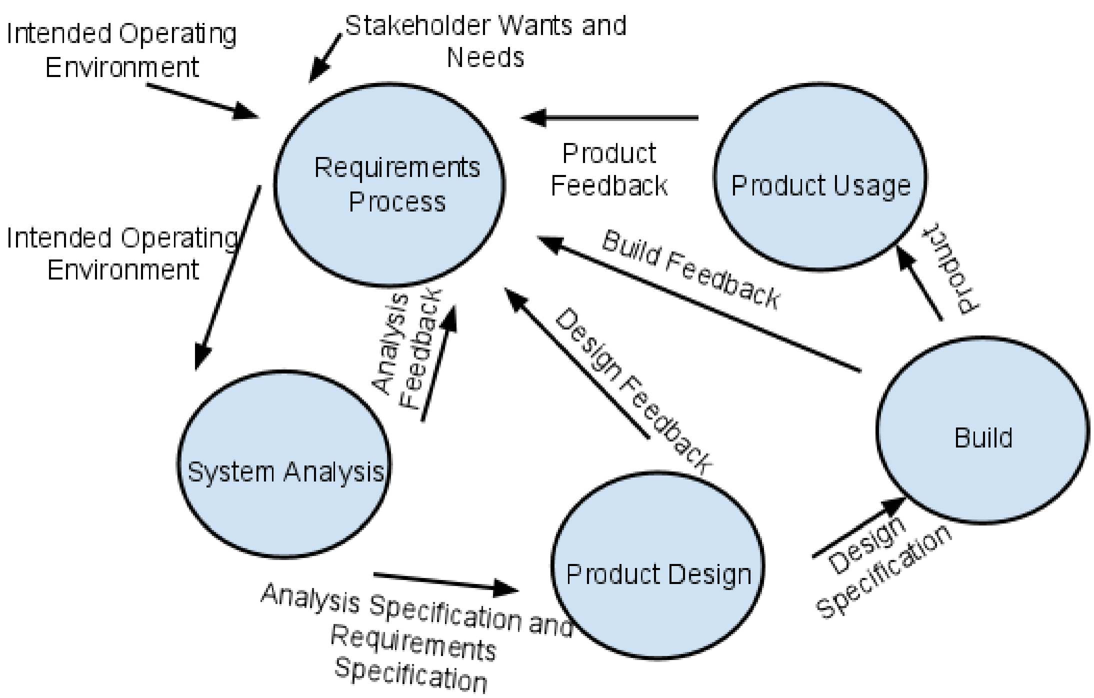

Figure 4

Functional and Data Requirements:

- The product shall determine if a loss occurs.
- The product shall accept modifications to resources.
- The product shall retrieve the frequency of events.
- The product shall retrieve a list of resources.
- The product shall retrieve the type and priority of an event.
- The product shall retrieve the time required for an event.
- The product shall retrieve the amount of resources needed for an event.
- The product shall retrieve the location of a resource.

- The product shall maintain an updated resource list. Mathematical model shall estimate the risk value and range at each event representing in dollar loss and loss lives.

Look and Feel Requirement:

- The product shall have the same layout as the most recent base installation map.

Usability Requirement:

- The product shall be usable to people with minimal guidance.

Ease of Learning Requirement:

- The product shall be used by the Program Director's staff that will have a training session.

Precision Requirement:

- The product shall maintain all monetary values accurate to two decimal places.

Reliability and Availability Requirement:

- The product shall be available for use during business hours.
- The product shall have a dependency on the base station budget.

Maintainability and Portability Requirements:

- The product is expected to run under Windows XP and 7.
- Data shall be updated and result accuracy shall be checked constantly for simulation and modeling accuracy.

Legal Requirement:

- The product must comply with NFPA (National Fire Protection Association) standards.

Off-the-shelf solutions:

- The product will incorporate FESPOM cost estimation when analyzing loss.

Cost:

- Cost model has been generated and provided by our sponsor.

2.1 Data Collection

Listed below are documents that were examined and the data collected from them.

Navy Fire and Emergency Services 2008

- Installation Name
- Frequency of Events
- Square footage
- Population
- Dollar loss
- Casualties
- Number of fire stations

Fairfax County Fire and Rescue Department 1997 – 2010

- Budget
- Casualties
- Dollar loss

Required Data:

- X and Y values for each location (Latitude and Longitude)
- Resources at each station
- Frequency of event
- Loss and lives (Cost associated)

2.2 Interviews

Steve Burke, volunteer fire fighter

The team interviewed Steve Burke, a volunteer fire fighter with 20 years of experience in rural fire departments. Mr. Burke provided data about F&ES functionality and operations. In his experience average response time per event was 6 minutes and heavily dependent on distance from the station to an event. He believed it was safe to assume similar dispatch system operation technology throughout all the stations. He also believed in assuming resources can be set to the desired availability and accessibility for all stations. In rural communities the event radius coverage per station was estimated at about 25 miles. The total number of events per year is about 5000. The majority of the calls are emergency medical services (EMS) that usually do not require a fire department resource. National Fire Incidents Reporting System (NFIRS) runs events investigation report after each event and are published in the reporting and data archive system.

Standard of Guidance (SOG) and Standard of Procedures (SOP) were used as references to detail firefighting handling procedures.

Minor accidents are resolved in about 30 minutes. Major accidents are resolved in about 1.5 hours. The times depend on the severity of the event and the availability of resources. Fire stations treat the simultaneous events based on the distance, resource availability, and events priority. The dispatch system identifies the event distance and then checks on the station's resource availability. The availability is based on the type, size, and severity of the event.

Fire Stations typically send two engines plus one ladder for full residential events. HAZMAT events does not have an exact time to resolve and can vary drastically depending on the size and type. HAZMAT events can take as little as 8 hours or as long as one week to fully resolve and are difficult to determine the proper resources. The difficulty depends on the strategies to stop the damage and can include chemical burns or explosions.

Captain Tom Arnold, Fairfax County Fire and Rescue

Captain Tom Arnold was able to meet for an interview at the Fairfax County Fire and Rescue Headquarters. The captain provided details of their operations. Response times follow the National Fire Protection Association standards. Fairfax County follows the 1710 response guidelines. The volunteer and career departments have different standards for response. The first response should arrive between 5 and 6 minutes. Additional response can arrive around 9 minutes.

EMS events occur 70 percent of the time. Fairfax County has 37 engines. One engine with a staff of 4 and an ambulance with a staff of 2 are used for a medical response. A minor medical event can last between 15 and 25 minutes. A major medical event can last 1.5 hours. There are both advanced and basic life support medical events.

When a false alarm occurs, it can five to fifteen minutes to resolve and fifty percent of the time the false alarm is cancelled. A good intent event consists of smoke (i.e. barbecue) instead of an actual fire event. It may take up to 90 seconds to leave the station.

Fairfax County Fire and Rescue use the Automatic Vehicle Locator (AVL) as their GPS system. The dispatcher inputs the type and location of the event and takes about a minute to enter the call. There is an algorithm with the system to calculate how many and what type of units are needed.

Simultaneous medical events that occur are usually at nursing homes. When a simultaneous event occurs, other units that are not being used are dispatched.

When a building is on fire, all available resources are sent to the event and may consist of 4 engines, 2 ladders, 1 rescue squad, 1 paramedic, 2 battalion chiefs, 2 captains, and a safety unit.

A single family home fire can take 2 to 3 hours, where as a townhouse building fire can take 5 to 8 hours. When there is a vehicle fire, one engine is used and an ambulance. The vehicle fire event may take up to half an hour. For brush fires, one engine is used and take 15 minutes to an hour to resolve and will involve an investigation.

The HAZMAT team consists of a unit and support vehicle. A HAZMAT event can take up to a day, but on average is one to two hours. There are 8 rescue squads. A technical rescue consists of 4 units, 6 assists for support, lumbar pod, 4 boats, and 1 fire boat. There are two special hazard units that absorb spills. The mobile care is for accidents that result in mass causalities. A mass ambulance bus is also available for that event. There are a total of 10 brush units.

A unit can be out of service during training, called brown outs. If the budget is reduced, administrative staff would be the first to be decreased. When coverage is transferred to another station, a “move up” has occurred. Move up monitor (MUM) is the automated system to track these events. Other operations include salvage and overhaul after a fire has been resolved.

Active stations receive about twelve to fourteen events per day. The non-active stations can receive one call per 3 to 4 days. Weather events consist of electrical wires down, floods, swift water, and tornadoes. Resources for weather events are used when available and are called holding calls. A service call is when a non-emergency event occurs.

3 TECHNICAL APPROACH

3.1 Design Alternatives

3.1.1 Methodology Alternatives

The tacit assumption of this study is by having less F&ES resources available it is more likely to result in unfavorable outcomes.

The initial approach was to analyze the historical data of thousands of events across hundreds of installations to seek correlations between event failures and the levels of resources available.

Fortunately, with the (CPL) already existing in the reporting, the data for resources available was already binned into categories, obviating the need to define and determine their levels. The total data set would “merely” need broken out by CPL level to see if providing lower resources resulted in greater losses in aggregate. This is displayed in figure 6. There was a large “if” that the correlation exists in the first place. But if it did, this correlation of loss to reduced resources could then be extrapolated into a predictive model usable to answer the overall problem.

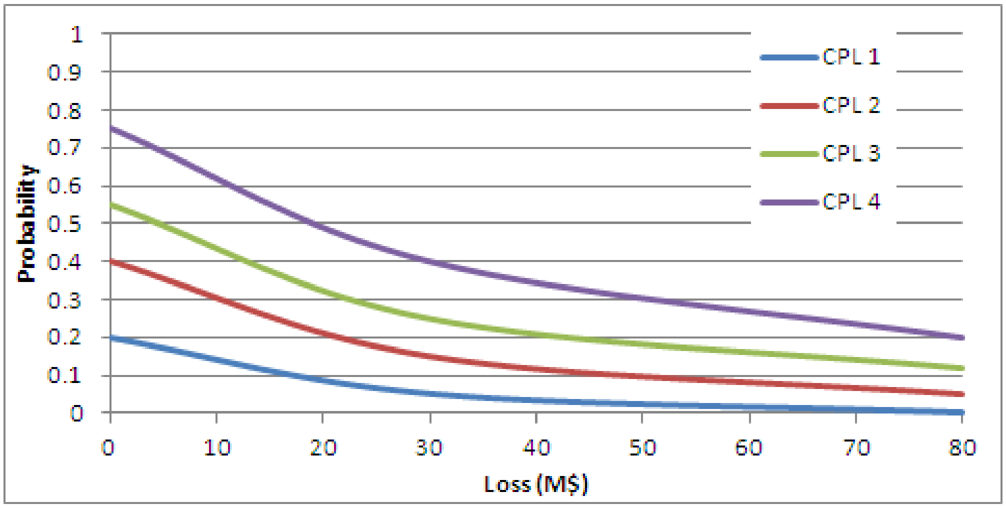

Figure 5

Unfortunately, the reality is that CPL levels are reported by the individual installations to show that they are able to meet policy requirements and standards with minimal, low, medium, or substantial risk. This reporting method provides implicit bureaucratic pressure to typically respond with “able to meet standards at this time, provided no additional resources are cut”.

Hence this limitation of CPL failing to provide data meaningful for this approach returns us to the original problem statement of needing to measure loss given varying levels of resources.

With this realization, we inverted our approach of determining loss given varied resource levels from top down to bottom up, focusing on simulating the response of individual vehicles to single events at the installation level. The number, locations, and abilities of vehicles would be modeled and varied to meet the demand of events randomly distributed by type, time, and place. This was the approach followed for this project.

3.1.2 Technical alternatives

The team looked into three different modeling tools to simulate the results: Arena, ExtendSim, and Excel. Both Arena and ExtendSim are simulation tools that use building blocks to explore the processes and enable the user to visualize the processes logically or in a virtual environment. The simulation tools analyze the impact of new, “what-if” business ideas, rules, and strategies before implementation. Both tools are able to run thousands of simulations quickly. Mr. Woodaman does not have an ExtendSim or Arena license, which counts against the project’s ability to be expanded upon later. In addition, Mr. Woodaman is not familiar with the Arena logic, which further prohibits expansion.

However, Mr. Woodaman has a license to Excel and most individuals have easy access to Excel allowing for near universal adoption of the model. Excel Macros allow the tool to be more powerful than just a spreadsheet analyzer, but macros require a certain amount of programming knowledge. Macros use Visual Basic syntax.

The team decided to use Microsoft Excel to model the problem because of the wide availability of the software leading to more acceptance and growth in the future.

3.2 Scoping

The team was given data for over 70 bases around the world. The purpose of this project was to develop a methodology to analyze various base configurations, allowing for different quantities and types of vehicles. Therefore, we decided to limit the analysis to only one base. Furthermore, instead of using an actual base to model events we decided to use the George Mason University (GMU) Fairfax campus. This was done because the team did not want the results to be linked to any particular base. While we believe the model is analytically strong, there is a tendency for individuals to attack the results based on emotional ties to the implications rather than on the analysis. The GMU Fairfax campus was used because it is similar in size and structure to some naval bases.

3.3 Scenarios

The team did not have access to the various configurations a naval institution might choose so three scenarios were designed to resemble potential options. The first scenario includes three on-site stations that have various vehicle types located with them and a local community station that can respond to a call on base. This scenario closely resembles the setup at a particular naval station. The second scenario includes the same three on-site stations with the same capabilities, but the local community station cannot respond to events on the base. This scenario was designed in order to stress how the base is capable of responding to events with only their own equipment. The third scenario has two on-site stations and can use the local community station to respond to events. This scenario was designed in order to understand how a closure at one station due to budget constraints would affect the stations ability to respond to events.

3.4 Alternate Solutions

In an actual situation the user will be designing scenarios dependant upon the budget. The user will have the ability to close stations, modify the number of vehicles at each station, the type of vehicles located at each station, the training personnel received, hours they work and locations personnel are deployed to. The FESEBLE product has the ability to model each one of these options other than personnel modifications.

3.5 Cost Estimation

The FESPOM model already provides a means of cost estimation. An overview of the FESPOM model process is that it first calculates the number of vehicles required by function to meet the expected demand based upon inspectable square footage and an input level of acceptable risk. It then determines the size of duty crew required per vehicle adjusted for 24/7 manning and cross training as well as the appropriate administrative support. The total costs for the equipment and personnel are then calculated. The FESPOM model's expected costs of various naval installations closely matches the reality of existing F&ES budgets. This similar conclusion by an independent method verifies the accuracy of the FESPOM model for estimating costs. Thus, the user can calculate the costs of varying resources levels through the FESPOM tool. Notice that the requirement for the acceptable risk of loss are independently determined and input into FESPOM by the user. This again highlights the overall problem of this study - to find a means of calculating loss given varied resources.

4 MODEL

4.1 The Code

The code randomly determines the time, place, and type of the next event using an exponential distribution based on the historical data of how many events of each type occurred at each location in one year. The type of event determines the number and types of vehicles necessary to respond. Vehicles are assigned based on whether they are of the appropriate type, undergoing maintenance, are already assigned to an event with a higher priority, and how close they are to the event. Each type of event has a probability of being a false alarm.

Vehicles are still assigned to false alarms, but the event duration is set to thirty minutes. If not all required vehicles are available, the event suffers a loss (zero loss if a false alarm). Vehicles that are already assigned to a previous event with a lower priority than the current event may be re-assigned to the current event in which case the previous event suffers a loss. After the full duration of an event occurs, all remaining vehicles assigned to that event are released to return to their home station.

4.2 Data Inputs & Assumptions

The team made assumptions about the various inputs for the tool when the data was not otherwise available as a source. Most of the assumed data is feasible to collect, given further time to do so.

One hundred locations were selected on the GMU map to be simulated based on the density and layout of the campus rather than modeling an installation (refer to the Scoping section).

The number and types of vehicles available at each station were based on the Program Compliance Assessment (PCA), but the locations of the stations were modified to the GMU map. Vehicles were assumed to be unavailable due to maintenance for 5% of the time, based on interviews.

The types and counts of events were based on the PCA. Some high loss, low probability events that did not historically occur, but which were addressed in the PCA were added so that they could occur in the simulation, albeit rarely. The counts of events historically occurring by location were assumed. The loss and lives associated with each event were assumed. The priority for the events was assumed primarily based on the associated risk to monetary loss and life. The duration of each event was based on discussion during the SME interviews. While the simulation will allow different probabilities of false alarm based on the type of event, they were set to a constant based on the PCA. The vehicles required based on the type of event were assumed, but are available from the Fairfax County Fire Department's dispatching tool.

4.3 Modeling Assumptions

Distances are used to determine which vehicles should attend to the event. Distances are calculated based on straight line distances between locations. For this run of the simulation, distances are unit-less values, but could be either distance or time.

All vehicles are assumed to be fully staffed with properly trained personnel. The tool's inability to account for training, cross manning vehicles, duty cycle/quality of life, etc. greatly reduces the solution space in the problem of what can be altered to reduce costs. See the Modeling Next Steps section for a potential improvement that addresses this. Vehicles are assumed to be unavailable an input percentage of time for maintenance, but this is determined independently for each event rather than on a scheduled basis.

Events are assumed to happen on an exponential distribution independent of each other, as well as independent of the time of day or season of the year.

If an event does not have all necessary vehicles attending it at the beginning of the event for the full duration, then it suffers a full loss. From interviews, it is most critical that all vehicles be at the event during its first thirty minutes, after which vehicles can become available for release. See the Modeling Next Steps section for further discussion.

False alarms still require the same amount of vehicles assigned to them so as to properly tax the system, but only for thirty minutes and if the event is not fulfilled there is no loss.

4.4 Runs

The team ran one hundred simulations of one year for each of the three scenarios. The first run for each scenario started with the same random seed number in order to minimize result randomness due to different event types. One simulation took a computer with 1GB RAM and MS Windows XP Operating System using Microsoft Excel 2003 roughly six minutes to complete. In order to complete all the runs, the machine ran for thirty hours.

4.5 Outputs from each run

In order to draw conclusions and comparisons between the scenarios and multiple simulations, output was drawn from each of the individual runs. These outputs include data on the monetary loss, lives lost, arrival times, failed events, and which vehicle shortage caused the failed event. Table 3 below shows the output from one run

Table 2

		Run 1
Total Monetary Loss		124.2
Total Lives Lost		2
Arrival Time for the First Responder	**Median**	1.17
	1st Quartile	0.60
	3rd Quartile	2.19
	Mean	2.23
	Standard Deviation	4.21
Arrival Time for the Last Responder	**Median**	1.17
	1st Quartile	0.61
	3rd Quartile	2.20
	Mean	2.27
	Standard Deviation	4.28
Count when First Responder was above 2 minutes		2328
Number of Failed Events		93
Number of Events Where Lives were lost		4
Vehicles	**ARFF**	0
	Battalion Chief	0
	Hazmat	0
	Ladder	0
	Rescue	0
	Structural Engine	95
	Tanker	0

5 RESULTS

5.1 Results

Comparing the sum of events that occurred by type in one year from the historical data with the output of a single run of the simulation resulted in a correlation of 0.999994 which does not verify that the code is accurately modeling reality, but does validate that the code is acting as expected.

Table 4 below shows the average monetary loss and the lives lost from the three scenarios. Scenario 1 which included the most amounts of available resources and stations had the least amount of lost dollars and lives. Scenario 2, which disabled the use of the community station, had the largest amount of lives lost. Scenario 3 lost a similar amount of lives that Scenario 1 had but it did have significantly higher monetary losses than Scenario 1.

Table 3

	Monetary Loss		Lives Lost	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Scenario 1	110.04	16.13	1.16	3.95
Scenario 2	341.17	105.55	27.65	4.85
Scenario 3	362.95	89.77	1.87	1.17

The ability for the first responder to arrive at the event within two minutes is critical to effectively react to the situation. Therefore, the percentage of time a vehicle is able to respond within two minutes is critical to the decision maker. Table 5 below shows this metric.

Table 4

	Percentage of Time the First Responder Arrivals within 2 minutes
Scenario 1	68.3%
Scenario 2	72.3%
Scenario 3	62.1%

Scenario 2 performed best in this measurement. This can be explained because they would not respond with any outside resource so more often a local vehicle attending an event had to leave this event, causing the number of failed events to increase, but lowering the average response time of the first responders for the events that were met. Scenario 3 was the worst performer due to the fact that they had the least amount of local stations that were able to respond to the event.

The team also captured the standard deviation of the metrics. These measurements are shown in Tables 6 and 7 below. In many of the metrics, the standard deviation was lowest for the third scenario. This happened because the vehicles had a similar response time to each event. Therefore, while it may not always respond in the ideal way, it will respond consistently.

Table 5

	Monetary Loss		Lives Lost	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Scenario 1	110.04	16.13	1.16	3.95
Scenario 2	341.17	105.55	27.65	4.85
Scenario 3	362.95	89.77	1.87	1.17

Table 6

	Count when First Responder arrived after 2 minutes		Number of Failed Events		Number of Events When Lives were lost	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**	**Mean**	**Standard Deviation**
Scenario 1	2372.50	51.80	94.77	15.50	1.87	4.09
Scenario 2	2074.22	49.00	403.58	49.43	28.23	5.01
Scenario 3	2842.18	59.32	366.21	25.53	2.54	1.53

5.2 Conclusions

In conclusion, the tool will be very useful to the user. FESEBLE methodology provides a clear, repeatable, and analytical way for determining the effectiveness of various solutions. Given proper input data for vehicle types, event locations, and station equipage a user can deliver accurate comparisons between different budgeting scenarios. In addition, this tool is flexible, adaptable, and scalable. The user can capture more metrics for each run by making simple additions to the code. Modifications to the station locations and equipage data or event probabilities can be done without code changes. All of the changes can be entered in the spreadsheets.

6 RECOMMENDATIONS & NEXT STEPS

6.1 Insights and Recommendations

The team recommends the user to experiment with various scenarios within the model to comprehend the depth and breadth of the tool. This will enable to user to see what metrics they find useful for themselves and get an understanding of any metrics that may need to be added into the model for their analysis. The team developed some additional features and next steps that can be completed for any further on work.

6.2 Next Steps

The model developed by the team currently has notional input data. In order to conduct a cost benefit analysis for the Navy, a site survey should be done at one base and the information should be populated into this model. The experience learned from this task will be very advantageous. First the end user will be able to analyze the tool for any additional features that would be needed or desired. Secondly, the site survey will feed an analyst with the appropriate inputs, which will lead to outputs for a particular base. With each of these components, a subject matter expert can design several scenarios using cost data to provide for various run types that the analyst can model and then report on. The outputs from the model will deliver the benefits for each scenario while the costs provided to make each scenario would be used in the preliminary cost/benefit analysis.
In addition, Fairfax County Fire & Rescue has a tool known as the Automate Vehicle Location. This tool determines the vehicles required for every event Fairfax County Fire & Rescue responds to. This information will greatly assist in identifying the vehicles required for the naval bases events, as well as provide additional fidelity to the analysis.

6.2.1 Ways to improve the model

While the probability of a vehicle not being available due to maintenance is modeled, the tool assumes that each vehicle is fully staffed with appropriately trained personnel able to provide one capability. Having resources capable of providing more than one capability expands the model to incorporate personnel levels and training. The simulator could have an event list the number of vehicles by each capability, as well as the number of personnel with which training, required for that event. Cross-staffing of vehicles by personnel as well as their training in technical or confined rescues could then be evaluated. Our interviews with Fairfax Country Fire Department demonstrated their willingness to set us up with further data concerning their means of determining which resources are pre-calculated as necessary for an event based on its type and intensity which could be useful for this improvement to the model.

Presently the code has a binary loss function – either all the necessary vehicles are available at the beginning of the event for the entire duration, or a loss occurs. For F&ES, the first 30 minutes are usually the critical time when all assets are needed. It would be more realistic to change the code so that having assets during that critical period is scored much higher than requiring them all to stay on station for the full event duration.

6.2.2 Lessons Learned

There were several lessons learned from this project. Some of these lessons learned were advice that was given to us by Dr. Loerch but still not implemented immediately. This includes defining the problem as early as possible. The team should have spent more time initially meeting with the sponsor to nail down the real problem and solution. This would have required the team to write out a preliminary proposal and vet it against the sponsor, allowing the sponsor to understand where the team was going and correct our course. Instead, originally both parties were talking in ambiguous terms about the solution without a clear understanding of what either side meant.

During our interviews with the experts, we should have asked them point blank questions about their experience. Instead, the team spoke to the experts about the model and tried to get them to fit their data into the model’s methodology. Looking back on this, the team should have turned the methodology into input questions that the experts would understand and answer.

On the coding front, all programmers should be aware of the coding style and method that will be implemented throughout the code. In one particular instance one programmer started their arrays on 0 while the other programmer started on 1. This led to a great deal of confusion and reworking of code that could have easily been avoided.

7 Appendices

7.1 Appendix References

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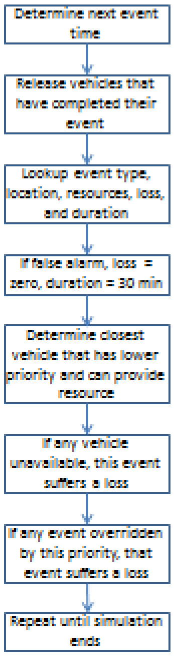
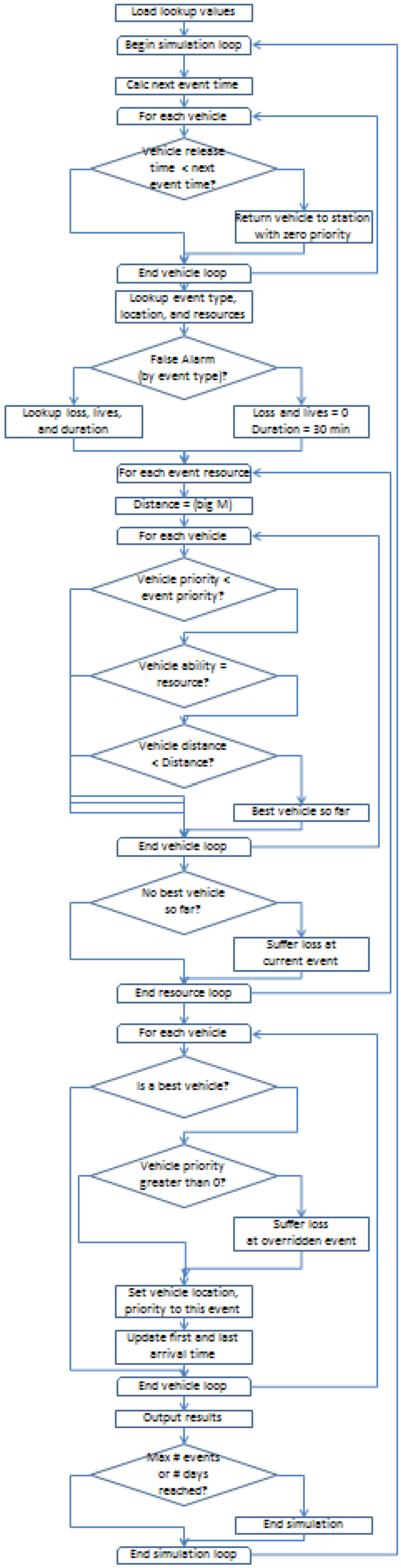
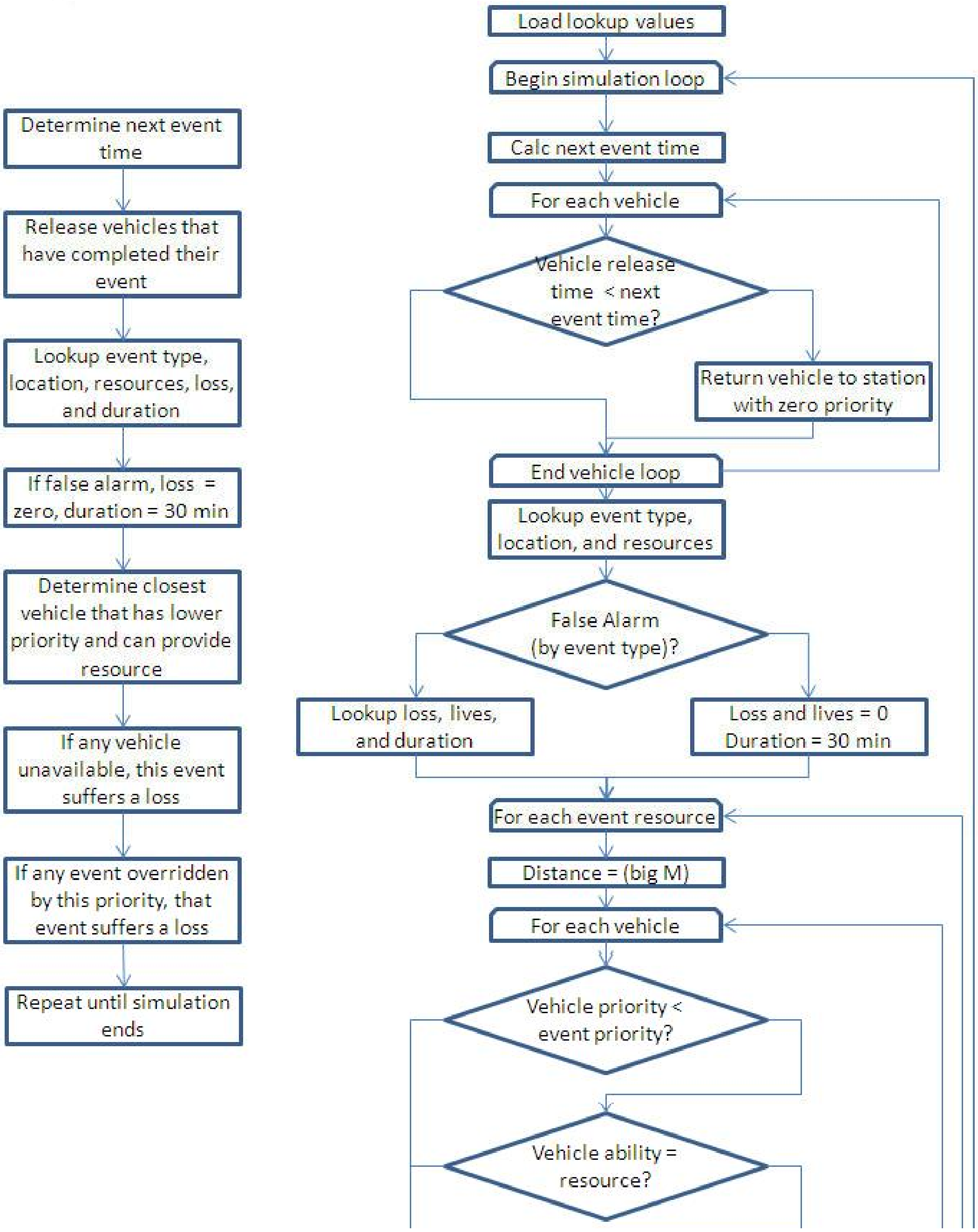
7.2 Appendix Flow Chart and Pseudo Code

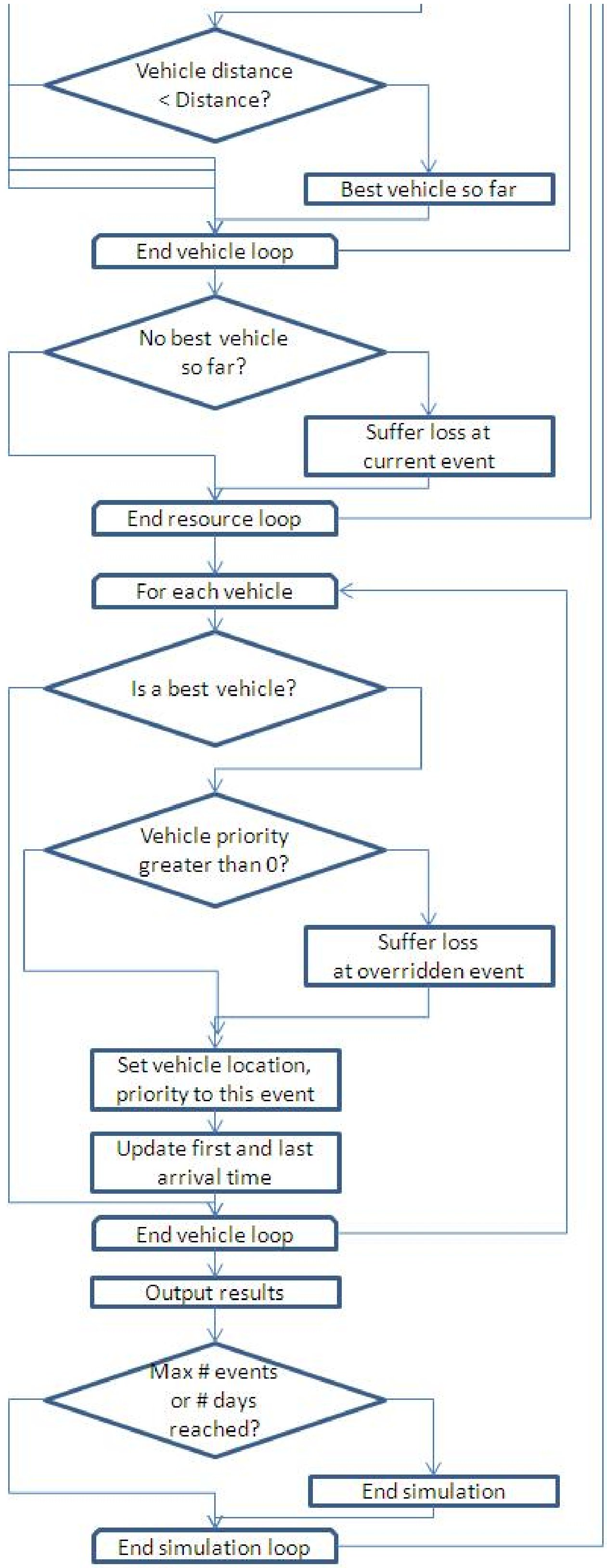


Determine next event time
Release vehicles that have completed their event
Lookup event type, location, resources, loss, and duration
If false alarm, loss = zero, duration = 30 min
Determine closest vehicle that has lower priority and can provide resource
If any vehicle unavailable, this event suffers a loss
If any event overridden by this priority, that event suffers a loss
Repeat until simulation ends



Load lookup values
Begin simulation loop
Calc next event time
For each vehicle
Vehicle release time < next event time?
Return vehicle to station with zero priority
End vehicle loop
Lookup event type, location, and resources
False Alarm (by event type)?
Lookup loss, lives, and duration
Loss and lives = 0 Duration = 30 min
For each event resource
Distance = (big M)
For each vehicle
Vehicle priority < event priority?
Vehicle ability = resource?
Vehicle distance < Distance?
Best vehicle so far
End vehicle loop
No best vehicle so far?
Suffer loss at current event
End resource loop
For each vehicle
Is a best vehicle?
Vehicle priority greater than 0?
Suffer loss at overridden event
Set vehicle location, priority to this event
Update first and last arrival time
End vehicle loop
Output results
Max # events or # days reached?
End simulation
End simulation loop


Determine next event time
Release vehicles that have completed their event
Lookup event type, location, resources, loss, and duration
If false alarm, loss = zero, duration = 30 min
Determine closest vehicle that has lower priority and can provide resource
If any vehicle unavailable, this event suffers a loss
If any event overridden by this priority, that event suffers a loss
Repeat until simulation ends
Load lookup values
Begin simulation loop
Calc next event time
For each vehicle
Vehicle release time < next event time?
Return vehicle to station with zero priority
End vehicle loop
Lookup event type, location, and resources
False Alarm (by event type)?
Lookup loss, lives, and duration
Loss and lives = 0 Duration = 30 min
For each event resource
Distance = (big M)
For each vehicle
Vehicle priority < event priority?
Vehicle ability = resource?


Vehicle distance < Distance?
Best vehicle so far
End vehicle loop
No best vehicle so far?
Suffer loss at current event
End resource loop
For each vehicle
Is a best vehicle?
Vehicle priority greater than 0?
Suffer loss at overridden event
Set vehicle location, priority to this event
Update first and last arrival time
End vehicle loop
Output results
Max # events or # days reached?
End simulation
End simulation loop