NAVY FIRE & EMERGENCY SERVICES ANALYSIS FRAMEWORK

OR/SYST 699 Fall 2012

Faculty Presentation

December 7, 2012

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IDI Innovative Decisions, Inc.

Project Team

- Sponsor
  - Fred Woodaman, Innovative Decisions, Inc.
    - Navy FESPOM Support Contractor
- GMU Project Team
  - Adam Bever, GMU MSSE Candidate
  - Megan Malone, GMU MSOR Candidate
  - Saba Neyshabouri, GMU MSOR Candidate
- Instructor
  - Dr. Karla Hoffman, GMU

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Agenda

- Project Background
- Project Plan
- Analysis Framework Description
- Test Case
- Conclusions

Adam Bever

Project Background

Background

- Navy Fire & Emergency Services (F&ES) protects 70+ installations world-wide via four functions:
  - Fire Protection
  - Fire Prevention
  - EMS Transport
  - Aircraft Rescue & Fire Fighting
- Navy F&ES is under tight budgetary pressure and needs to quantify the impact of reductions in services.
- Long term goal would be to provide a loss-minimizing cost gradient that identifies the order in which assets are deployed from first dollar to last dollar.

Definition of Terms

- Company
- Apparatus/Fire Engine
- Mutual Aid
- Response Time

Previous GMU Work

- Fall 2011
  - Developed an Excel-based simulation of a generic installation with a simplistic loss function (0 or 1) driven by historical call data.
  - Model utilized GMU Fairfax campus as a stand-in for Navy base.
- Spring 2012
  - Developed a probabilistic loss model of the residential fire scenario.
  - Model focused only on single-family dwellings with a limited number of configurations.

Fall 2012 Project

- Modular hybrid approach
  - Utilize probabilistic loss model approach that allows for partial losses
  - Simplify an installation description
  - Utilize historical call data as base risk
- Desired result:
  - To provide the Navy with a framework tool for quantifying the expected loss of property as a result of reducing the fire and emergency services force size at any given base.
    - Measure of Performance (MOP): response time
    - Measure of Effectiveness (MOE): expected loss

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Project Goals

- To construct a model of a generalized installation that can be made specific given simple data for a particular installation.
- To build an efficient simulation model that will calculate expected losses using probabilistic loss models of various emergencies.
- To include and expand on the residential fire probabilistic loss model.
- To provide an interface to allow for simple addition of new probabilistic loss models for other emergency scenarios.

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Adam Bever

Project Plan

Methodology

- Agile development approach
  - Modified scrum techniques
  - Focus on highest ROI elements first
- Scheduling
  - Built in time for PM efforts
  - Divide and conquer development

Project Tasking

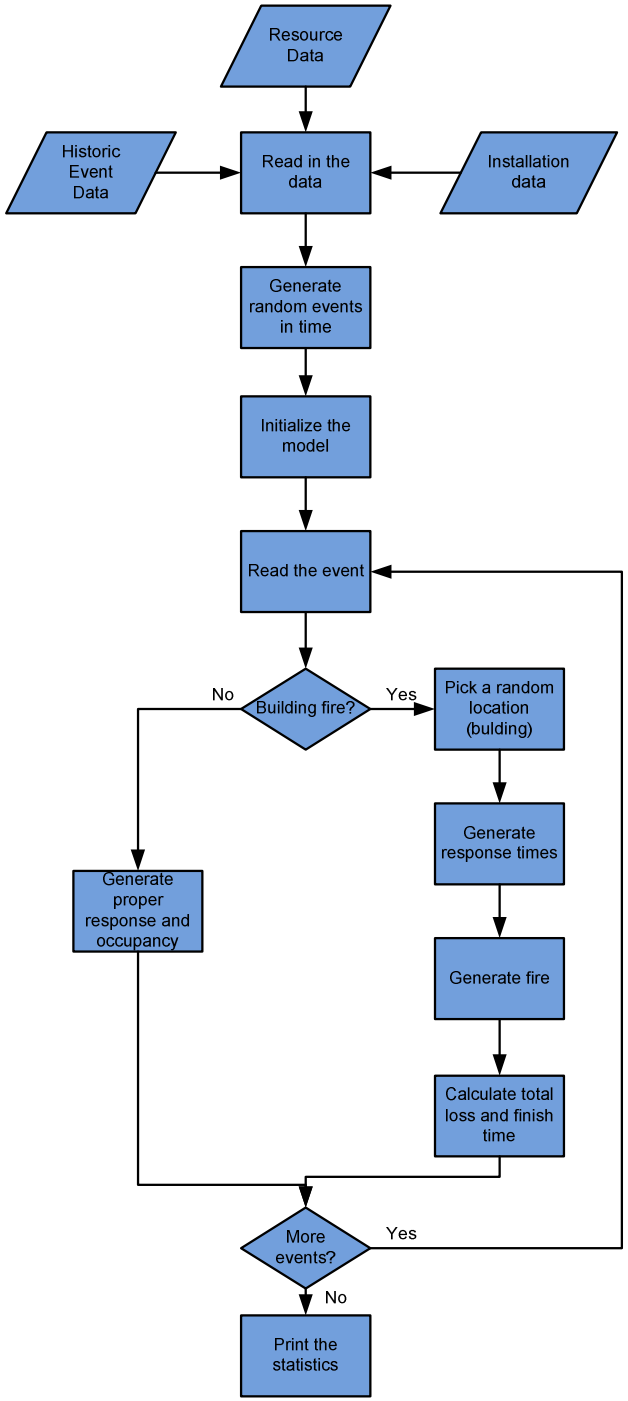
- Capture and decompose stakeholder requirements (All)
- Lay out a generic installation template (Adam)
- Encapsulate the Spring 2012 fire loss model (Saba)
- Construct incident generator and response model (Megan)
- Integrate final analysis tool (All)
- Build a real-world installation model (Adam)
- Conduct proof-of-concept analysis (All)

Saba Neyshabouri & Megan Malone

Analysis Framework Description

Overview

- Analysis tool developed in Excel with VBA backend
- Discrete event simulation
- User input split into coherent sections
  - Header
  - Buildings
  - Stations
  - Vehicles
  - Response Time
  - Call Data



Assumptions

- Real-world Navy installations can be generalized and adequately described by a relatively small set of parameters.
- F&ES force sizes are relatively small and integral, such that forces cannot necessarily be reduced by a given percentage.
- Response time is defined as the start of the incident until a response vehicle arrives at the location.
- Response time to a location within a cluster of buildings from a given fire station will be uniformly distributed +/- 2 minutes vs nominal response time to the cluster from the same fire station.
- Incidents are handled on a first-in first-out basis.
- F&ES events will occur with the same frequency over the next year as they have on average over the period specified in an installation's PCA report.

More Assumptions

- No building is any more likely to catch fire than any other building.
- Any building that catches fire begins in a state of good repair.
- F&ES vehicles must return to their assigned station before responding to another event.
- All vehicles may become unavailable for maintenance for a set period of time with a certain probability. This probability and length of unavailability may be set by the user.
- Vehicles are assumed to be fully manned when needed for an incident response.
- Vehicles at mutual aid stations are always available for use on the installation.
- Three fire engines will respond to all fires, pending availability. All selected vehicles will respond as soon as they are available.

Installation Template

Name	Dummy Base
Location	Nowhere, USA
Population	1000
Total Area (acres)	10
Buildings (excl. F&Es)	8
Base F&ES Stations	2
Mutual Aid Stations	1
Vehicles	20

Index	BuildingID	BuildingName	Type	Floors	Floor Area (sq ft)
1	8	Building A	Residential	4	600
2	23	Building B	Commercial	6	20000
3	52	Building C	Retail	1	5000
4	17	Building D	Warehouse	1	50000
5	9	Building E	Manufacturing	1	10000
6	13	Building F	Laboratory	3	20000
7	100	Building G	Dock	1	100000
8	200	Building H	Airfield	1	100000

Index	Station	Engines	Crew/Engine
1	Station 1	2	4
2	Station 2	1	4
3	Offsite 1	2	4

Index	Vehicle	Type	Location
1	Engine 1	Pumper	Station 1
2	Engine 2	Pumper	Station 1
3	Ladder 1	Pumper	Station 1
4	Ambulance 1	EMS	Station 1
5	HazMat 1	HazMat	Station 1
6	Command 1	Command	Station 1
7	Command 2	Command	Station 1
8	Engine 1	Tanker	Station2
9	Engine 2	Pumper	Station2
10	Engine 3	Pumper	Station2
11	Ambulance 1	EMS	Station2
12	Ambulance 2	EMS	Station2
13	Command 1	Command	Station2
14	Command 2	Command	Station2
15	Engine 1	Tanker	Offsite 1
16	Engine 2	Pumper	Offsite 1
17	Ambulance 1	EMS	Offsite 1
18	Ambulance 2	EMS	Offsite 1
19	Ambulance 3	EMS	Offsite 1
20	Command 1	Command	Offsite 1

Building Types	Vehicle Types
Residential	Pumper
Commercial	Tanker
Retail	EMS
Warehouse	HazMat
Manufacturing	Command
Laboratory	Auxilliary
Dock	
Airfield	

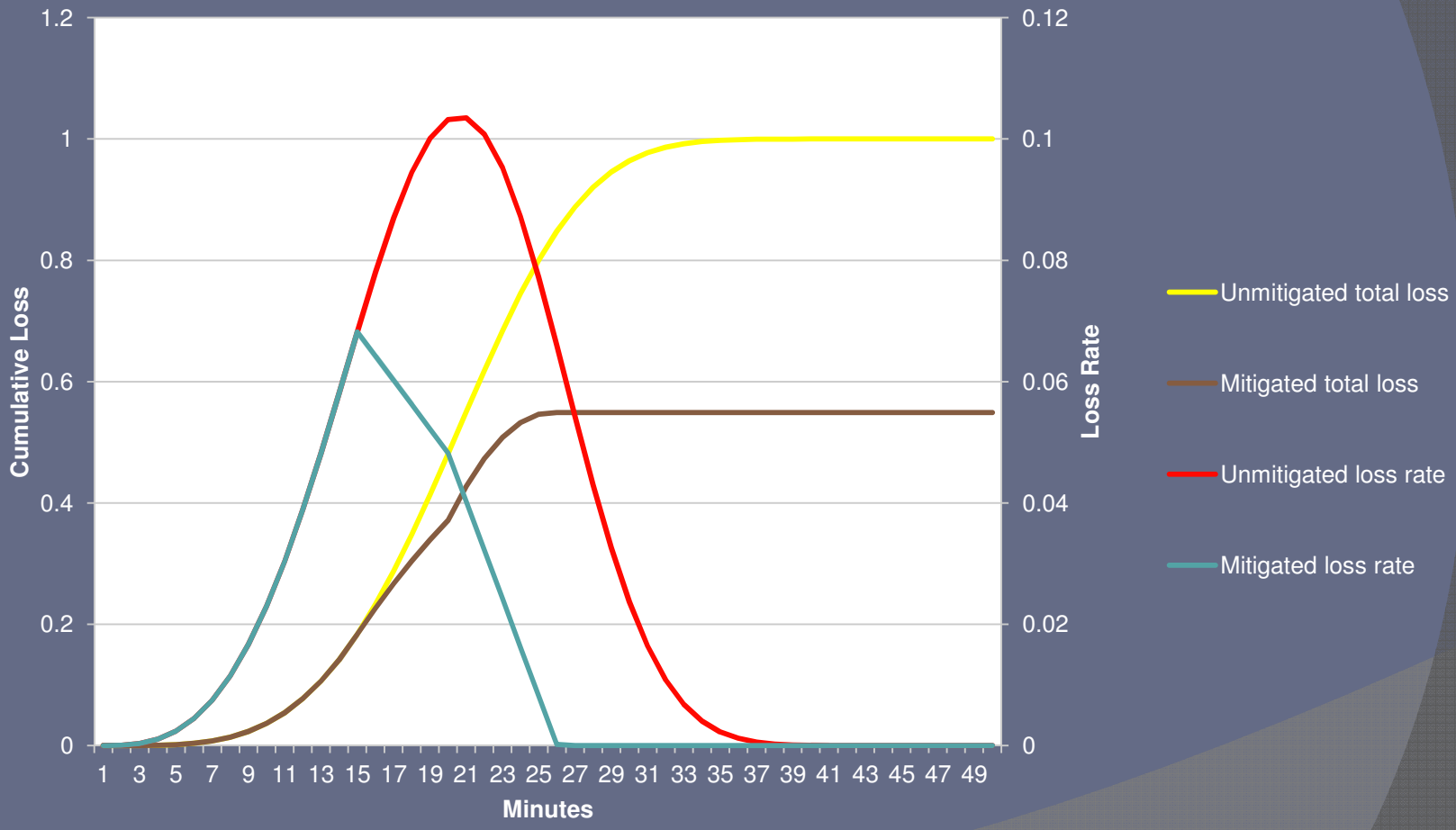
Response Time	Station Index	1	2	3
	Station Name	Station 1	Station 2	Offsite 1
Building Index	Building Name			
1	Building A	4	7	9
2	Building B	5	7	12
3	Building C	7	6	15
4	Building D	7	9	12
5	Building E	5	5	19
6	Building F	6	11	7
7	Building G	10	3	17
8	Building H	13	6	16

Period Start	01/01/04				
Period End	12/31/06				
Total Days	1095				
				Civilian	F&ES
Building Fires	15		Fire Injuries	0	0
Vehicle Fires	2		Non-Fire Injuries	0	0
Other Fires	46		Fire Deaths	0	0
Overpressure Ruptures, Explosion, Overheat	6		Non-Fire Deaths	0	0
Medical Treatment	796				
Other Rescue	150				
Hazardous Conditions	221				
Service Calls	458				
Good Intent	81				
Severe Weather & Natural Disaster	0				
Special Incident	6				
Unknown Incident	0				
Malicious False Calls	9				
Other False Calls	796				
Total Calls	2586				

Fire Loss Model

- Inputs - Arrival time for trucks 1, 2, & 3
- Outputs - % loss, time to completion
- Updates to previous work
  - If truck response time is too late for the linear mitigation to reduce loss, the loss is total.
  - Transformed step-wise spreadsheet model in closed form integral formula.

Fire Loss Model



Incident Generator

- Baseline probabilities derived from actual installation-specific call data (from PCA reports)
- Events are randomly generated over a 1-year span
  - Exponential distribution for interarrival times
- Only responding to building fires and vehicle emergencies
  - Hooks in code to handle other events

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Incident Response

- Events are randomly assigned to a building
  - Building groups are weighted according to multiplicity
- Vehicle availability based on priority list
  - Start with onsite vehicles, use mutual aid only if onsite unavailable
  - Randomly vary nominal response time between station and buildings in clusters
    - Uniform distribution
  - Utilize three fastest responders

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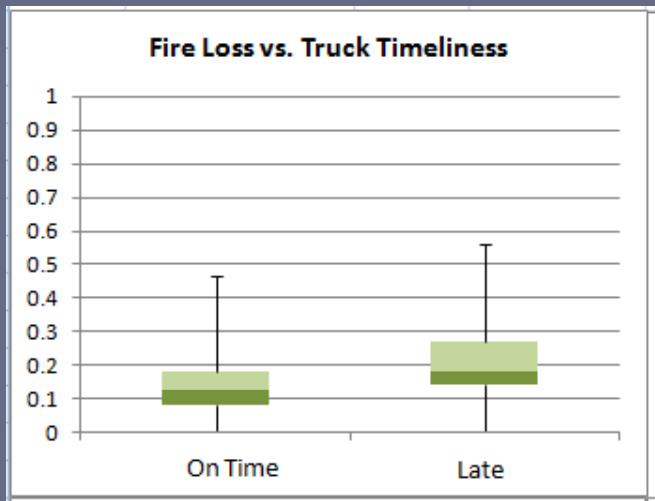
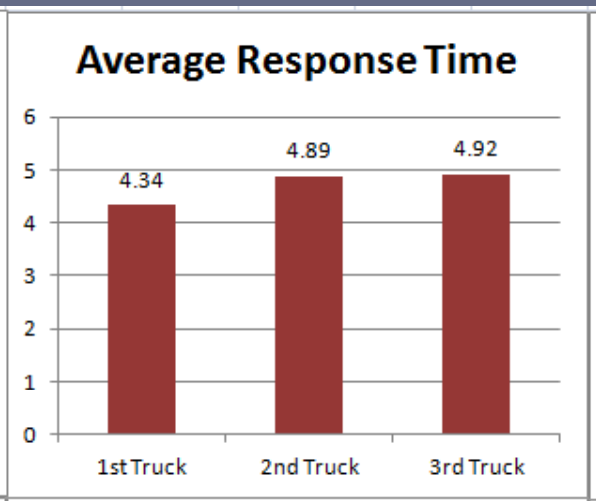
Sample Raw Output

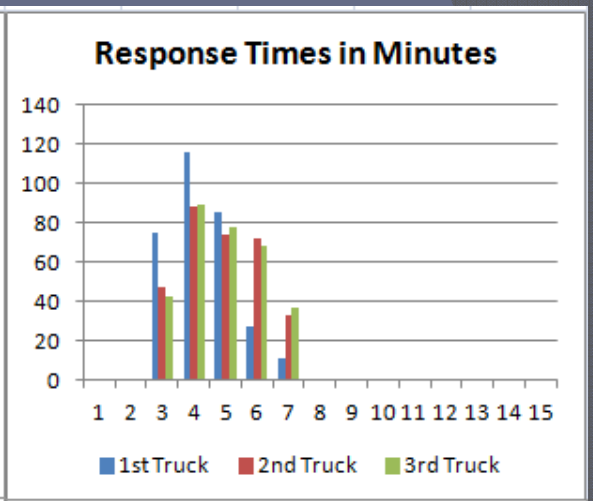
- Model results dumped to plain text file for further analysis in Excel, Matlab, or other tools.

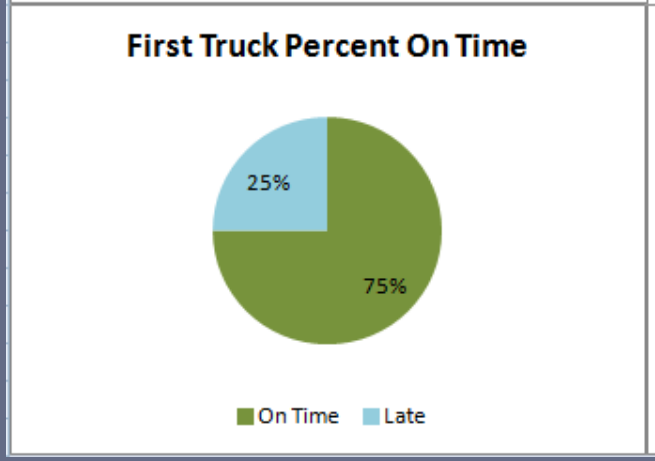
Event Type	Event Number	Replication	Start Time	Duration	Truck 1 Response Time	Truck 2 Response Time	Truck 3 Response Time	Location ID	Location	Damage
Building Fires	3	8	4515.42	78	5.37	5.82	5.82	PPV	PPV Housing	0.14
Building Fires	4	8	4599.57	79	3.11	6.24	6.24	PPV	PPV Housing	0.23
Vehicle Fires	5	8	5228.77	90	5.35	6.26	9999	PPV	PPV Housing	0.75
Building Fires	6	8	5389.54	80	4.9	4.9	4.9	PPV	PPV Housing	0.38
Vehicle Fires	7	8	5390.9	90	5.94	4.88	9999	PPV	PPV Housing	0.75
Building Fires	8	8	5559.83	90	4.81	4.81	4.81	CH 905	Morale Welfare & Recreation (MWR)/Youth Center	0.46
Building Fires	9	8	6320.04	77	4.45	4.45	4.45	PPV	PPV Housing	0.12
Building Fires	10	8	6629.69	76	3.93	3.93	3.93	PPV	PPV Housing	0.12
Building Fires	11	8	6959.73	74	3.15	3.15	3.15	PPV	PPV Housing	6.61E-002
Building Fires	12	8	7879.49	76	3.83	3.83	3.83	PPV	PPV Housing	0.17
Building Fires	13	8	7895.09	90	3.88	6.09	6.09	483	Public Works Dept	2.63E-003
Vehicle Fires	14	8	8074.95	90	5.32	6.41	9999	PPV	PPV Housing	0.75
Building Fires	15	8	8087.16	78	4.3	4.3	4.3	PPV	PPV Housing	0.22
Building Fires	16	8	8168.55	81	4.57	4.57	4.57	PPV	PPV Housing	0.4

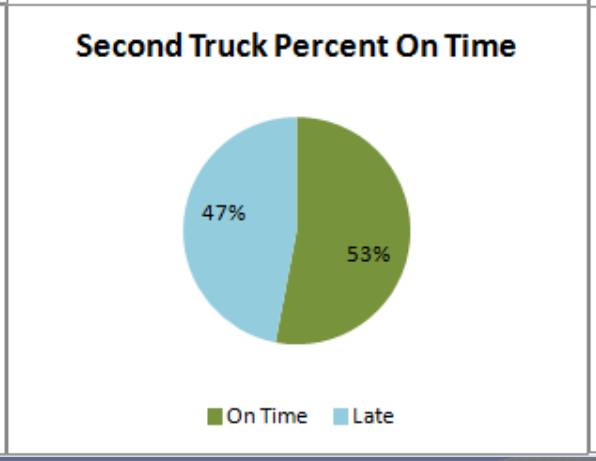
Sample Graphical Output

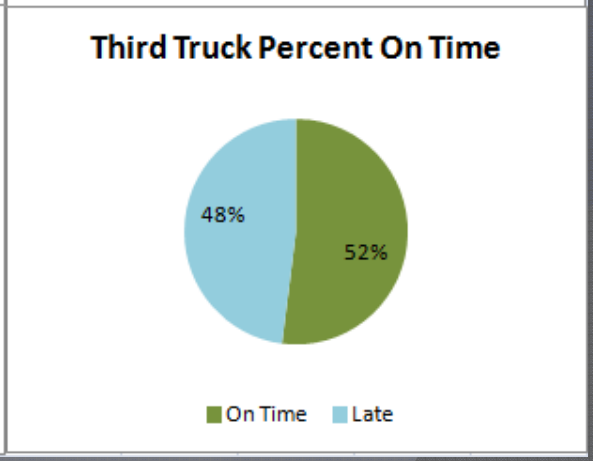












Megan Malone

Test Case

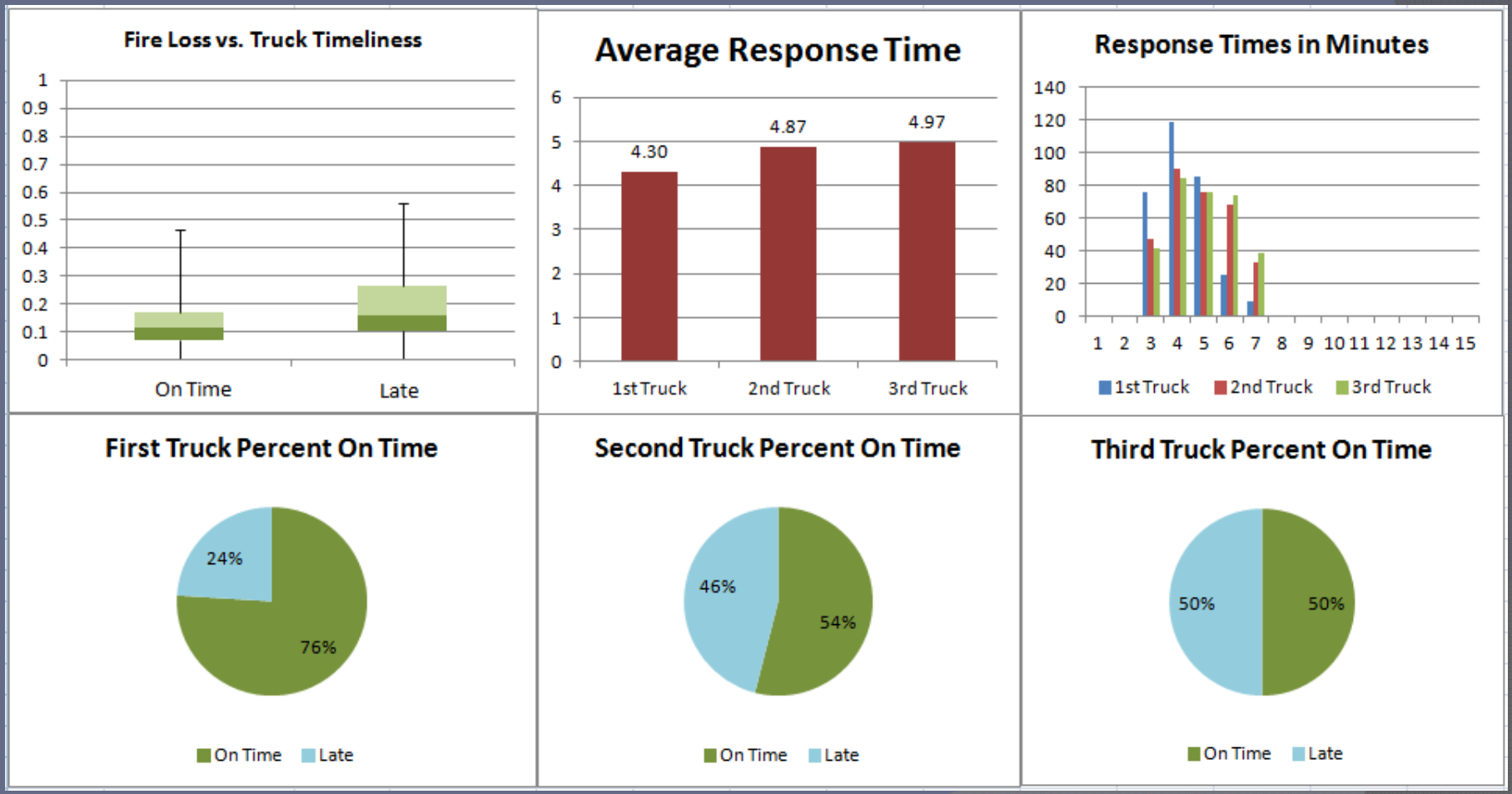
Base Selection

- Selected Submarine Base New London as test case
  - 2 onsite fire stations, 3 mutual aid stations
  - Wide variety of building types and sizes, including a significant residential component
  - No airfield

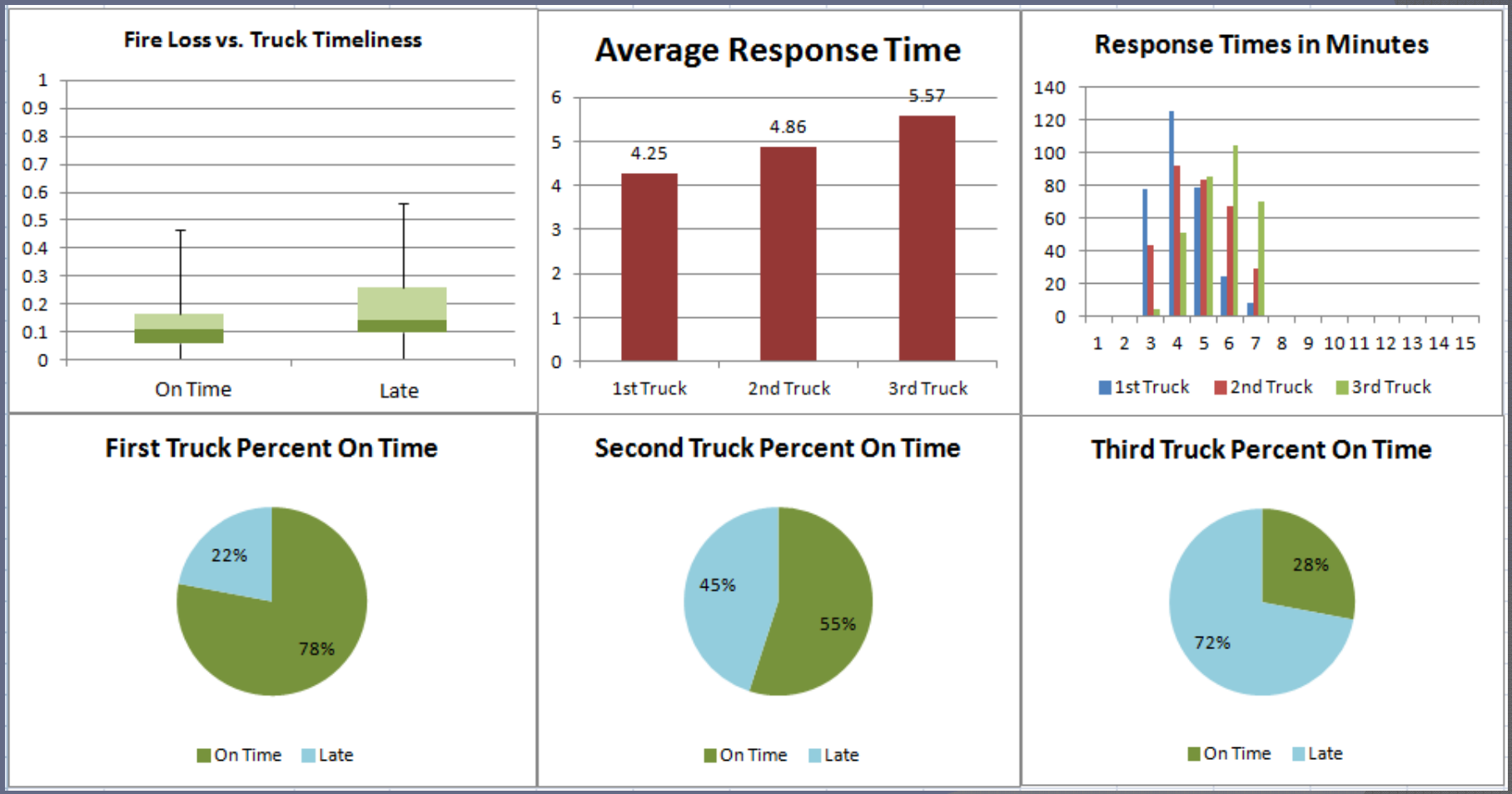
Test Case Scenarios

- Baseline
  - 30 1-year simulations
  - Utilize all onsite resources and mutual aid
- F&ES Reduction 1
  - Same conditions as baseline, except one company removed from station 1
- F&ES Reduction 2
  - Same conditions as baseline, except station 2 and corresponding companies removed

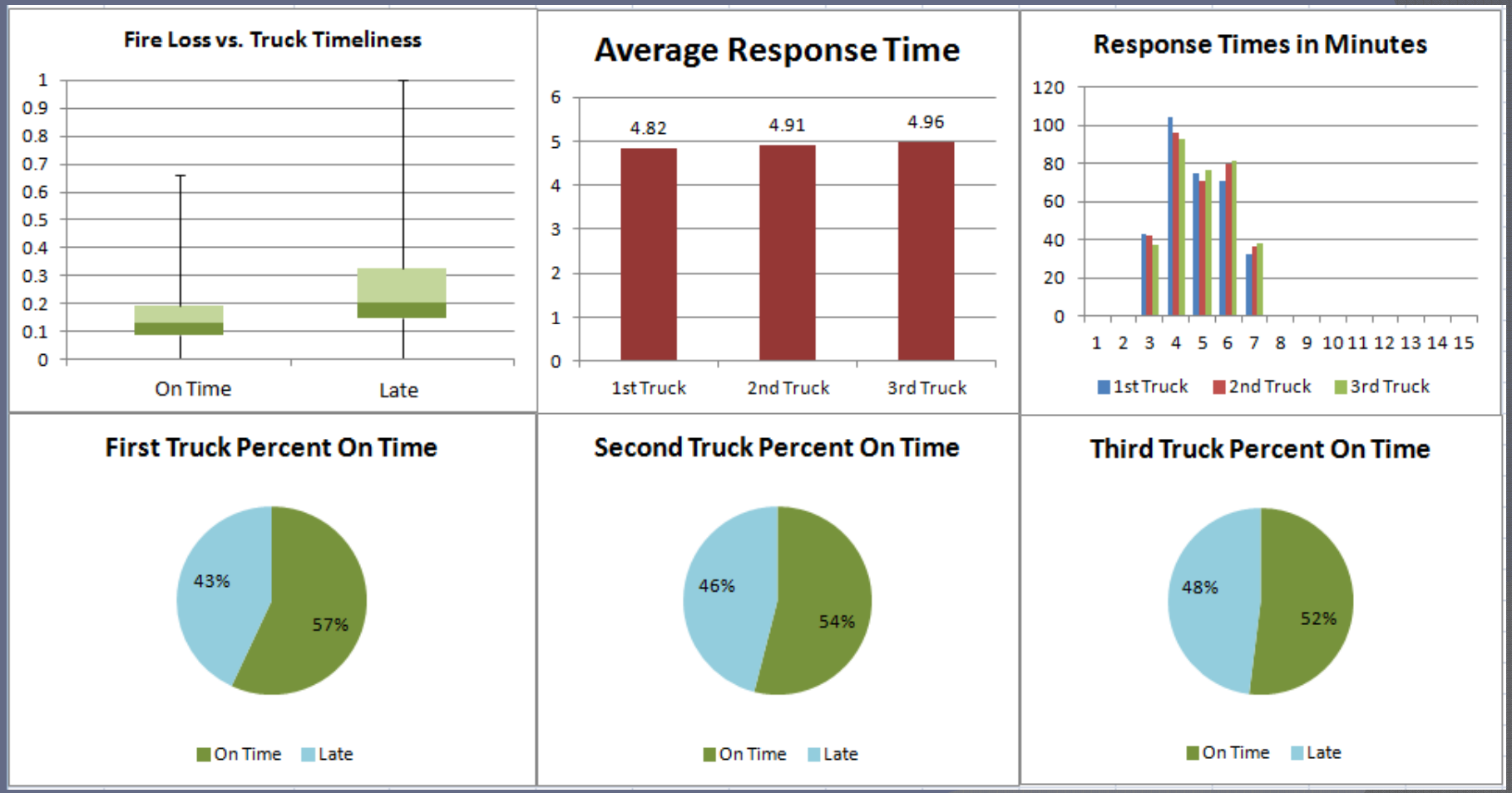
Baseline Results



F&ES Reduction 1 Results



F&ES Reduction 2 Results



Side-by-side Comparison

Measure	Baseline	Case 1	Case 2
Maximum loss (on-time arrival)	46.5%	46.5%	66.2%
Upper quartile loss (on-time arrival)	17.0%	16.6%	19.1%
Median loss (on-time arrival)	11.7%	10.7%	12.9%
Lower quartile loss (on-time arrival)	6.8%	6.0%	8.6%
Maximum loss (late arrival)	56.4%	56.4%	100.0%
Upper quartile loss (late arrival)	26.5%	26.2%	32.7%
Median loss (late arrival)	15.9%	14.5%	20.5%
Lower quartile loss (late arrival)	10.5%	9.9%	14.6%
Average response time (truck 1)	4.30	4.25	4.82
Average response time (truck 2)	4.87	4.86	4.91
Average response time (truck 3)	4.97	5.57	4.96
On time arrival percentage (truck 1)	76%	78%	57%
On time arrival percentage (truck 2)	54%	55%	54%
On time arrival percentage (truck 3)	50%	28%	52%

Test Case Analysis

- Reducing resources increases average response time (primary loss driver).
- Removing a single truck (2 remain at station)
  - Slight impact to average response time
  - No significant impact to average loss
  - Implication is that 3 trucks may not be necessary at this station (within given assumptions).
- Closing a station
  - Increases loss outliers and shifts loss distribution upwards, especially for late arrivals
  - Improvement in 3rd company arrival times due to heavier usage of mutual aid assets.

Adam Bever

Conclusions

Goal Review

- To construct a model of a generalized installation that can be made specific given simple data for a particular installation.
  - Done – buildings can be entered individually or in homogenous groups, call data from PCA reports
- To build an efficient simulation model that will calculate expected losses using probabilistic loss models of various emergencies.
  - Done – 30 1-year iterations at 1 minute-resolution take < 5s
- To include and expand on the residential fire probabilistic loss model.
  - Partially met – Could not locate large enough data sets for expansion of the existing residential loss model
- To provide an interface to allow for simple addition of new probabilistic loss models for other emergency scenarios.
  - Done – placeholders in code for other incidents

Conclusions

- Rather than providing answers to a limited set of questions, the framework allows the Navy to ask many different questions.
- Significant room for future growth and increased model fidelity

Recommendations

- Utilize XML import for installation template
- Conduct more research on fires in alternate building types
- Develop loss models for other, higher frequency events.
- Implement a priority list that allows assets to be redeployed directly from one incident to another of higher precedence.
- Increase fidelity of model to include crew skills.
- Conduct optimization analysis for ideal station placement following a force reduction.

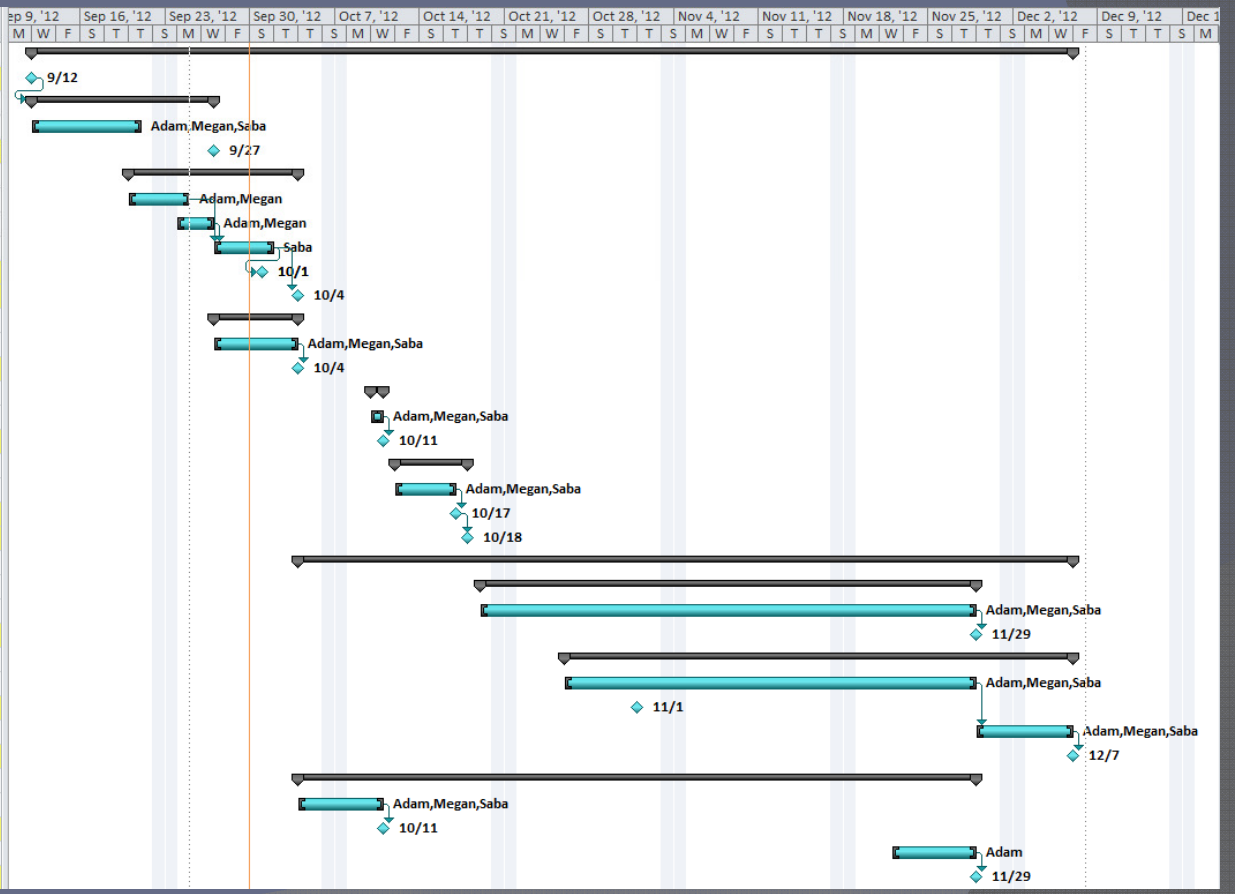
Thank you!

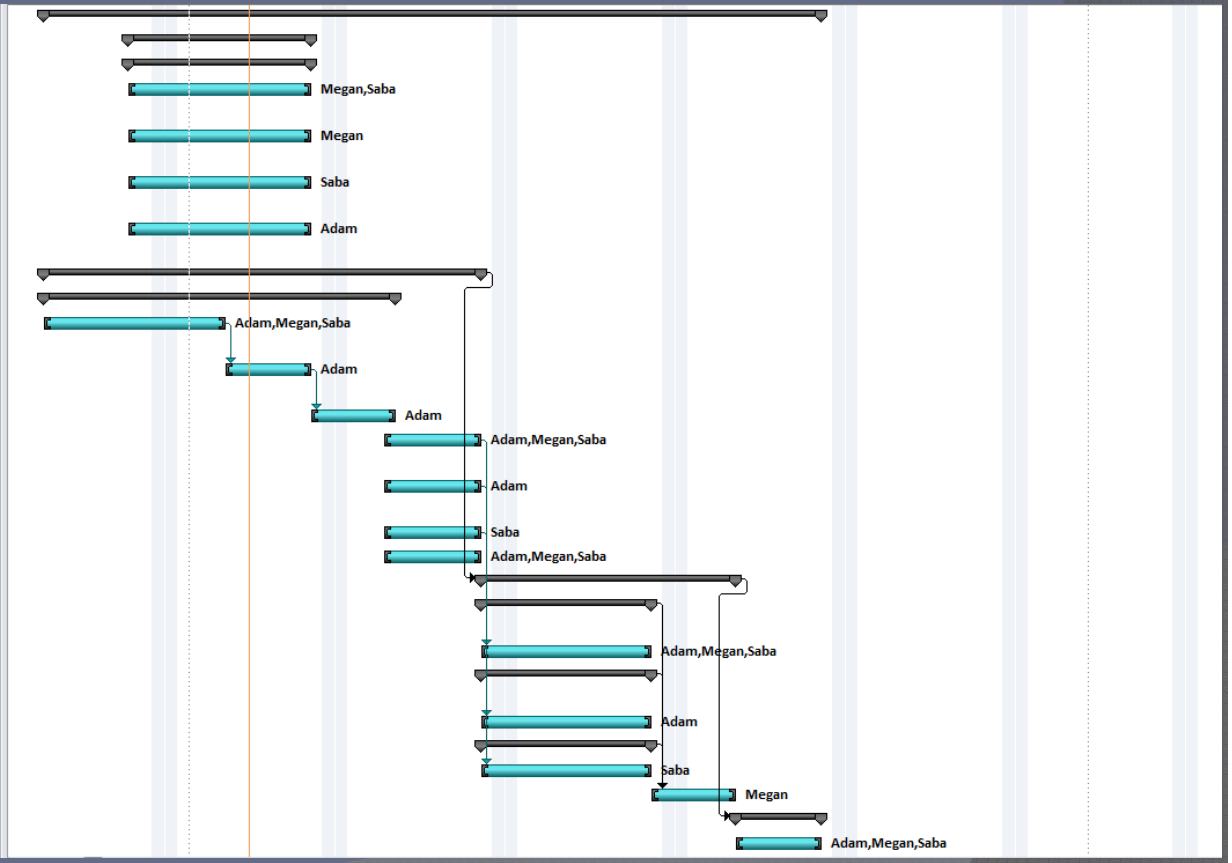
Questions?

Backup

PM Schedule

	WBS	Task Name	Duration	Start	Finish
1	**1**	Project Management	**62 days**	**Wed 9/12/12**	**Fri 12/7/12**
2	1.1	Project Kickoff	0 days	Wed 9/12/12	Wed 9/12/12
3	**1.2**	Develop Project Definition	**11 days**	**Wed 9/12/12**	**Thu 9/27/12**
4	1.2.1	Interview sponsor	7 days	Wed 9/12/12	Thu 9/20/12
5	1.2.2	Present problem definition	0 days	Thu 9/27/12	Thu 9/27/12
6	**1.3**	Develop Project Plan	**10 days**	**Thu 9/20/12**	**Thu 10/4/12**
7	1.3.1	Assign tasking	3 days	Thu 9/20/12	Mon 9/24/12
8	1.3.2	Layout project schedule	3 days	Mon 9/24/12	Wed 9/26/12
9	1.3.3	Generate slides	3 days	Thu 9/27/12	Mon 10/1/12
10	1.3.4	Submit project plan slides	0 days	Mon 10/1/12	Mon 10/1/12
11	1.3.5	Present project plan	0 days	Thu 10/4/12	Thu 10/4/12
12	**1.4**	Develop Project Proposal	**5 days**	**Thu 9/27/12**	**Thu 10/4/12**
13	1.4.1	Write proposal	5 days	Thu 9/27/12	Wed 10/3/12
14	1.4.2	Submit project proposal	0 days	Thu 10/4/12	Thu 10/4/12
15	**1.5**	Prepare 1-5 page status update	**1 day**	**Wed 10/10/12**	**Thu 10/11/12**
16	1.5.1	Write status update	1 day	Wed 10/10/12	Wed 10/10/12
17	1.5.2	Submit status update	0 days	Thu 10/11/12	Thu 10/11/12
18	**1.6**	Prepare IPR presentation	**4 days**	**Fri 10/12/12**	**Thu 10/18/12**
19	1.6.1	Generate IPR slides	3 days	Fri 10/12/12	Tue 10/16/12
20	1.6.2	Submit IPR presentation	0 days	Wed 10/17/12	Wed 10/17/12
21	1.6.3	Present IPR	0 days	Thu 10/18/12	Thu 10/18/12
22	**1.7**	Prepare final deliverables	**46 days**	**Thu 10/4/12**	**Fri 12/7/12**
23	**1.7.1**	Prepare final report	**29 days**	**Fri 10/19/12**	**Thu 11/29/12**
24	1.7.1.1	Generate final report	29 days	Fri 10/19/12	Wed 11/28/12
25	1.7.1.2	Submit final report	0 days	Thu 11/29/12	Thu 11/29/12
26	**1.7.2**	Prepare final presentation	**30 days**	**Fri 10/26/12**	**Fri 12/7/12**
27	1.7.2.1	Generate final slides	24 days	Fri 10/26/12	Wed 11/28/12
28	1.7.2.2	Submit presentation draft	0 days	Thu 11/1/12	Thu 11/1/12
29	1.7.2.3	Dry run presentation	6 days	Thu 11/29/12	Thu 12/6/12
30	1.7.2.4	Present project results	0 days	Fri 12/7/12	Fri 12/7/12
31	**1.7.3**	**Prepare project website**	**40 days**	**Thu 10/4/12**	**Thu 11/29/12**
32	1.7.3.1	Design website layout	5 days	Thu 10/4/12	Wed 10/10/12
33	1.7.3.2	Submit website design	0 days	Thu 10/11/12	Thu 10/11/12
34	1.7.3.3	Generate HTML	5 days	Thu 11/22/12	Wed 11/28/12
35	1.7.3.4	Upload files	0 days	Thu 11/29/12	Thu 11/29/12



Development Schedule

36	**2**	**Analytic Framework Development**	**46 days**	**Thu 9/13/12**	**Thu 11/15/12**
37	**2.1**	**Conduct background research**	**11 days**	**Thu 9/20/12**	**Thu 10/4/12**
38	**2.1.1**	**Break down previous models**	**11 days**	**Thu 9/20/12**	**Thu 10/4/12**
39	2.1.1.1	Identify inputs and outputs	11 days	Thu 9/20/12	Thu 10/4/12
40	2.1.1.2	Identify assumptions made	11 days	Thu 9/20/12	Thu 10/4/12
41	2.1.1.3	Identify underlying algorithms	11 days	Thu 9/20/12	Thu 10/4/12
42	2.1.2	Identify common installation features	11 days	Thu 9/20/12	Thu 10/4/12
43	**2.2**	**Design framework**	**26 days**	**Thu 9/13/12**	**Thu 10/18/12**
44	**2.2.1**	**Capture requirements**	**21 days**	**Thu 9/13/12**	**Thu 10/11/12**
45	2.2.1.1	Identify stakeholder requirements	11 days	Thu 9/13/12	Thu 9/27/12
46	2.2.1.2	Decompose into system requirements	5 days	Fri 9/28/12	Thu 10/4/12
47	2.2.1.3	Generate SRS	5 days	Fri 10/5/12	Thu 10/11/12
48	2.2.2	Design modular loss model interface	6 days	Thu 10/11/12	Thu 10/18/12
49	2.2.3	Design generic installation descriptors	6 days	Thu 10/11/12	Thu 10/18/12
50	2.2.4	Design data input modality	6 days	Thu 10/11/12	Thu 10/18/12
51	2.2.5	Design user interface	6 days	Thu 10/11/12	Thu 10/18/12
52	**2.3**	**Develop framework**	**15 days**	**Fri 10/19/12**	**Thu 11/8/12**
53	**2.3.1**	**Develop modular loss model interface**	**10 days**	**Fri 10/19/12**	**Thu 11/1/12**
54	2.3.1.1	Code model interface	10 days	Fri 10/19/12	Thu 11/1/12
55	**2.3.2**	**Develop generic installation descriptors**	**10 days**	**Fri 10/19/12**	**Thu 11/1/12**
56	2.3.2.1	Code installation handler	10 days	Fri 10/19/12	Thu 11/1/12
57	**2.3.3**	**Develop data input modality**	**10 days**	**Fri 10/19/12**	**Thu 11/1/12**
58	2.3.3.1	Code data handler	10 days	Fri 10/19/12	Thu 11/1/12
59	2.3.4	Develop user interface	5 days	Fri 11/2/12	Thu 11/8/12
60	**2.4**	**Test framework**	**5 days**	**Fri 11/9/12**	**Thu 11/15/12**
61	2.4.1	Develop test case from	5 days	Fri 11/9/12	Thu 11/15/12