NPS MDP Study
Outbrief Schedule, 1 JUN 2005

0800-0815 Introductions

0815-0915 Background/Results

0930-1015 Cargo Inspection System (Land)

1030-1130 Cargo Inspection System (Sea)

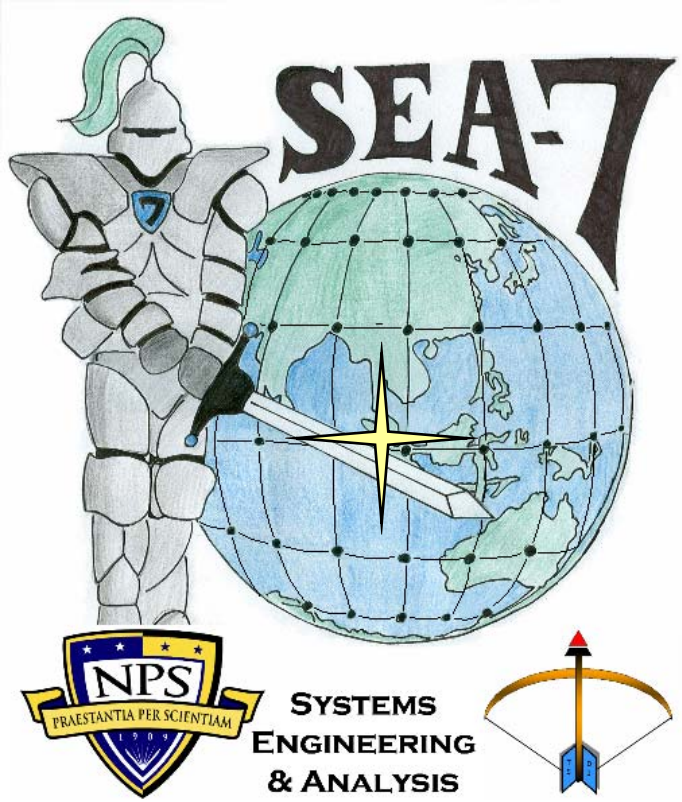
1130-1230 LUNCH

1230-1330 Sensor System

1345-1445 C3I System

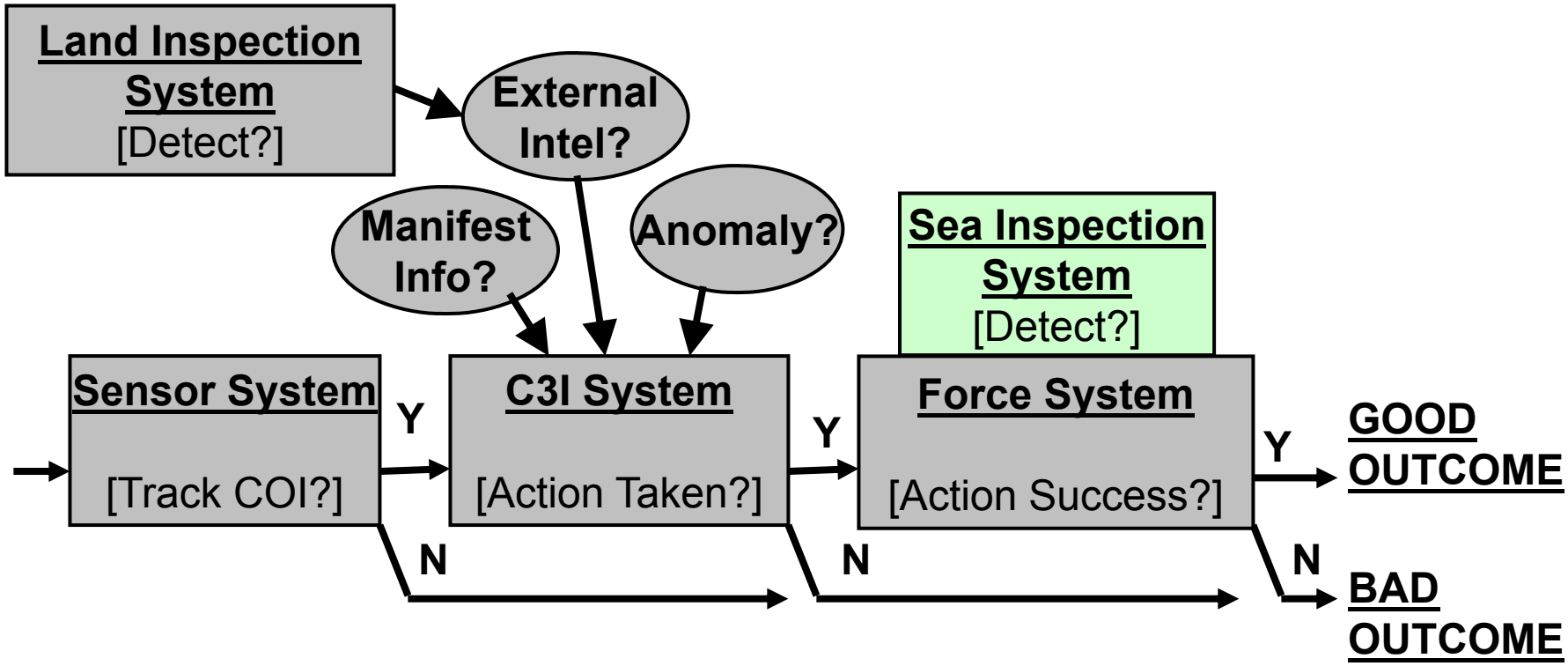
1500-1600 Response Force System

NPS MDP Study
Sea Inspection Group



LT MATT WIENS, USN

MDP System
Operational Architecture



Sea Inspection Agenda

- Bottom Line
- Objectives/Requirements
- Functional Decomposition
- Alternatives Generation
- Model Overview
- Model Assumptions
- Model Factors
- Results
- Conclusions/Insights
- Land Systems Integration

NPS MDP Study System Insights

Land Cargo Inspection

- Effective Cargo Inspection requires industry cooperation

Sea Cargo Inspection

- Enroute at-sea cargo inspections can be effective using current sensor technology, but effective C3I is required

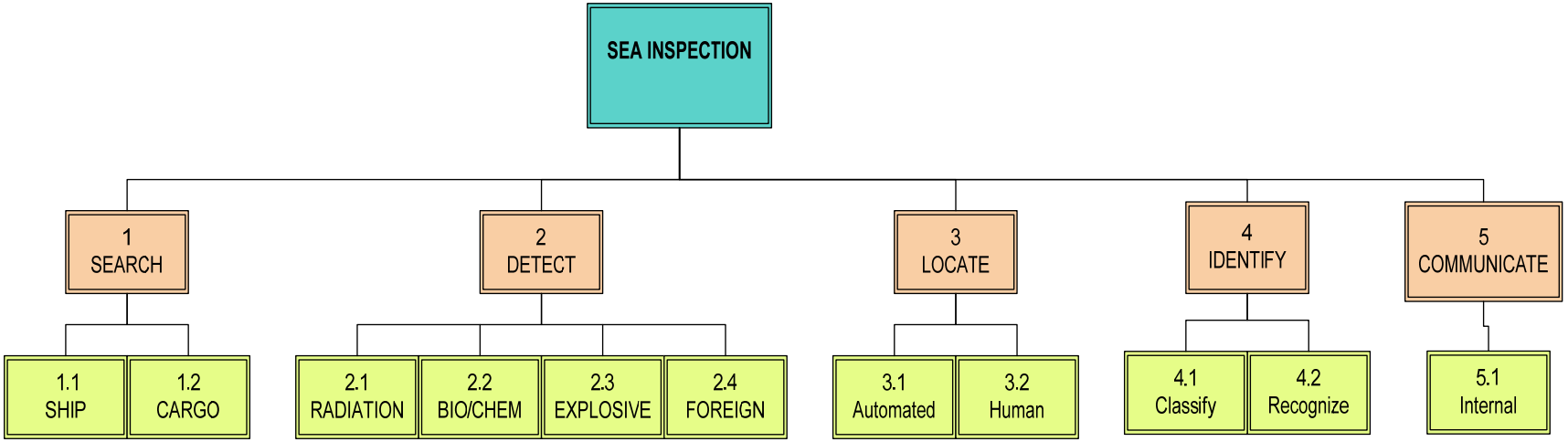
Sea System Group Objectives

- Characterize at-sea ship inspection system process
- Identify methods to improve container inspection process and minimize shipping delay
- Develop model for sea inspection system
- Determine driving factors for sea inspection system
- Recommend system alternatives to implement an at-sea inspection system

Sea Inspection Requirements

- Search 80% of ship in 6 hours
- 9 hr power source
- Portable sensor packages
- 24 hour availability of teams
- Compatible with maritime environment
- Communications b/w team members
- Components exist or viable within five years

Sea Inspection Functional Decomposition



“As-Is” SYSTEM

- NO AT SEA INSPECTION OCCURS
- SHIPPING COMPANY RESPONSIBILITY
- ANTI-TAMPER DEVICES ARE OPTIONAL
- CARGO TRACKED BY MANIFEST

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ALTERNATIVES GENERATION

SEARCH		
Interior	Exterior	Cargo
Secret agents	UAV	
Honor System	Mammals with sensors	Dog team
Dog Team	External Portable Monitor	
Manifest Comparison	check point platform with multiple sensors	
Robotic Inspection	Robotic Inspection	Robotic Inspection

DETECT				
NEUTRON	GAMMA	CHEM/BIO	EXPLOSIVES	FOREIGN OBJECTS
	ARAM (NAI Detector) Adaptable Radiation Area Monitor)	APDS (hard install)		
Imaging Device?	Backpack Sensor (HPGe) High purity Ge	APDS (portable) Airborne Particulate Det Sys	Swipes	
Neutron Detector	Imaging Device	Swipes	Dogs	Mammals
Radiation Sickness	GM Detector	Canaries	Mammals	Manifest Anomalies
		Symptom	Channel Mounted	Wide Band

LOCATE		IDENTIFY	
AUTOMATED	HUMAN INTERPRETATION	CLASSIFY	RECOGNIZE
Sensor Mapping	Human Search (smell Sight)		
Data Analysis	Imaging/Display	ARAM (NAI Detector) Sodium Iodide	ARAM (NAI Detector)
	Animal Indication	Lab Analysis	Lab Analysis
	Sickness Locality	Mass Spectrometer	Mass Spectrometer
	Intelligence		

COMMUNICATE
INTERNAL
IR
Radio (UHF, Walkie-Talkie)
Encoded Laser
Cable
Ultra Wide Band Radar (LLNL)
VHF Radio

Sea Inspection System Alternatives Overview

ALT 1: “Boarding Team”

- **24 hour rule (manifest data)**
- **Ships screened by algorithm**
- **Human Inspection Teams**

ALT 2: “Honor System”

- **Required level of security standards**
- **SMART devices on containers**
- **Human Inspection Teams**

ALTERNATIVE 1
BOARDING TEAM INSPECTION SYSTEM

- 24 HOUR RULE FOR MANIFEST DATA
- SHIPS SCREENED BY ALGORITHM
  - MANIFEST DISCREPANCIES
  - COURSE DEVIATIONS
  - SHIP HISTORY
  - INTELLIGENCE
  - OTHER ANOMALIES

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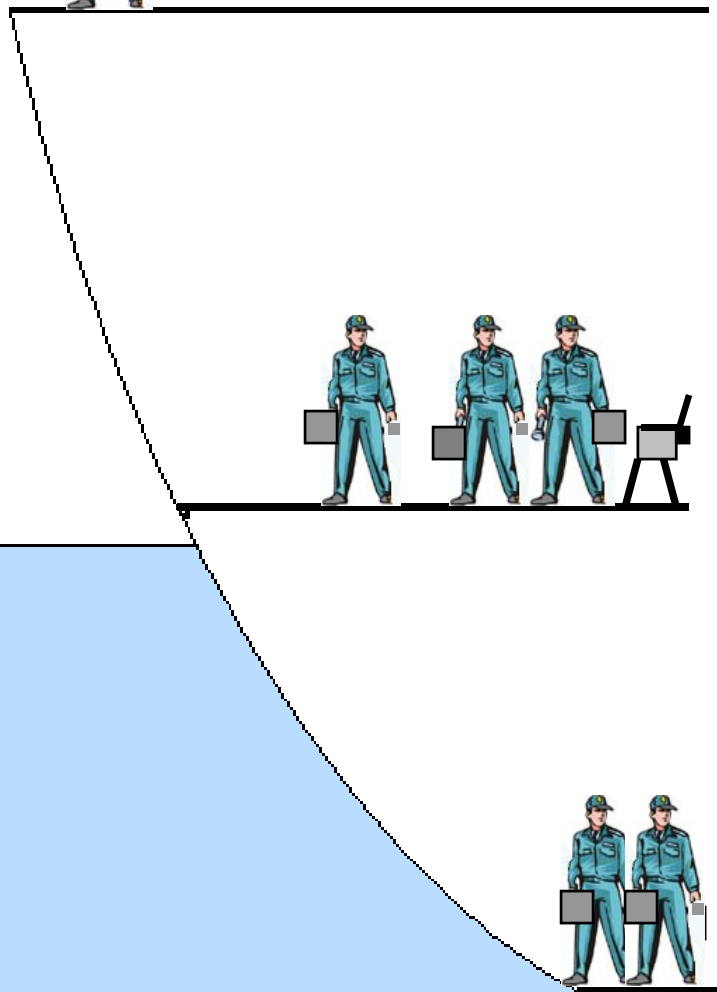
ALTERNATIVE 1: BOARDING TEAM INSPECTION SYSTEM

- Teams inspect ship for explosives, contraband and manifest anomalies.
- Review shipping documents for manifest anomalies
- Communications maintained with portable radios



- **Portable Gamma Imager**
- **Spectrometer**
- **Portable radiation detectors**
- **Swabs for explosives**
- **M-8/M-9 paper chemical**
- **M245A1 nerve agents**
- **Bio detection device**

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ALTERNATIVE 2
HONOR INSPECTION SYSTEM

- **Shipping companies must meet following guidelines to bypass boarding team inspection.**

  - SMART container devices working on all containers
  - Accurate/Timely manifest data (24 hr limit)
  - No SMART container alarms
  - “Clean” ship history, including crew
  - Port of call accuracy

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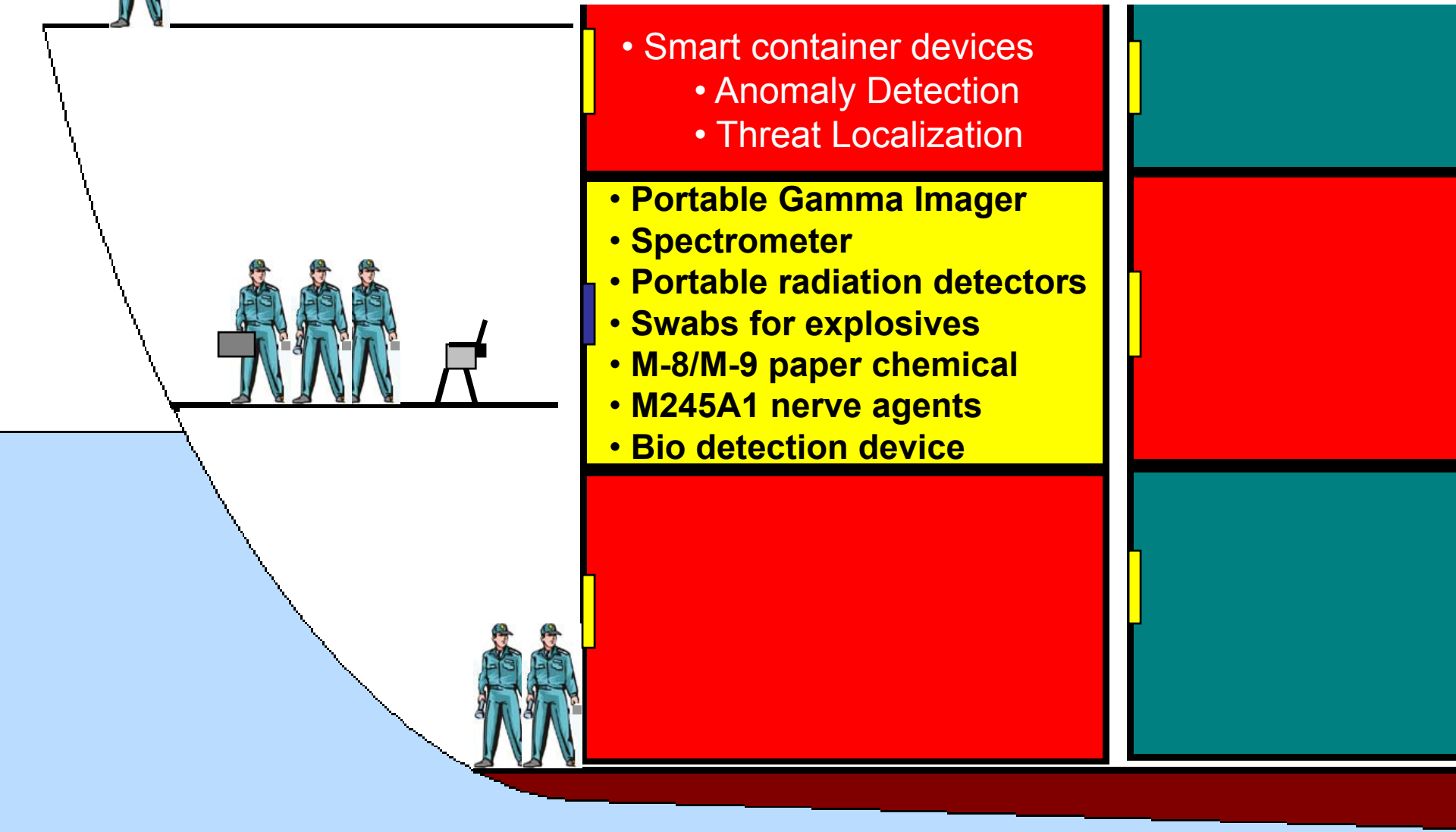
ALTERNATIVE 2: HONOR INSPECTION SYSTEM

- Teams inspect ship for explosives, contraband and manifest anomalies.
- Review shipping documents for manifest anomalies
- Communications maintained with portable radios



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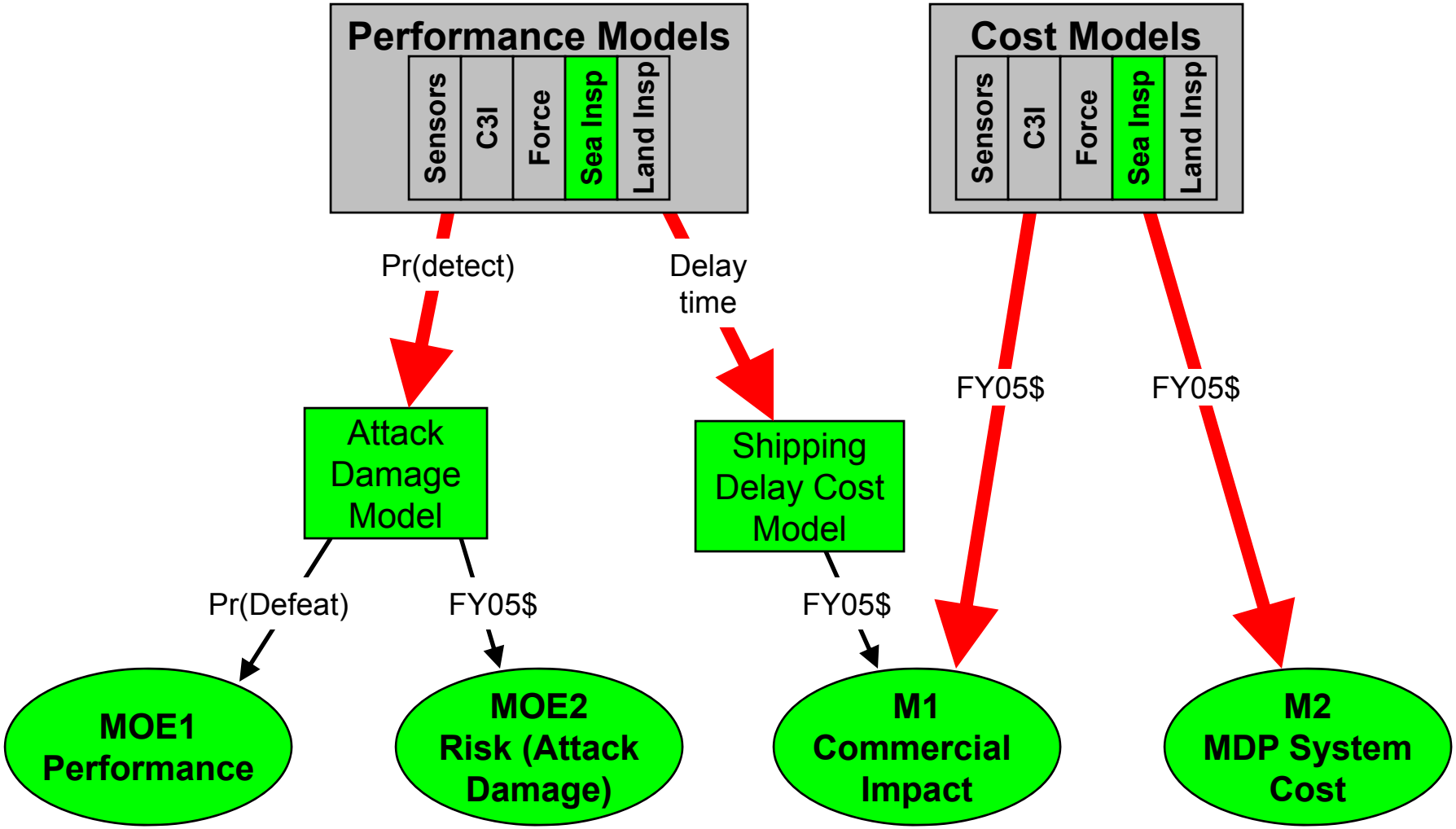
Overarching Modeling Plan



Sea Inspection Model Assumptions

- Used EXTEND^{tm} for modeling
- ~10,000 ships/year
- Ships detected 300-250 nm from shore
- Ships needing inspection wait for teams to be available
- 1 hour turn-around time for inspection teams
- Teams available around the clock
- Boarding team detection = 36 hr detention
- Avg US container value was used for delay cost ($ 25K)

Sea Inspection Model Parameters Factors Considered

- # Inspection Teams/Shift
- Inspection Time
- Soak Time
- P(Rand Inspection)
- P(d) & P(FA) Smart Container
- P(d) & P(FA) Boarding Team
- Team Turnaround Time
- Number of ships/year

RED : Factors varied

Sea Inspection Model Overview

Input Variables

- Shipping Data (size, #)
- # Inspection Teams/Shift
- Inspection Time
- Soak Time
- P(random Inspection)
- P(d) & P(fa) Smart Container
- P(d) & P(fa) Boarding Team

→

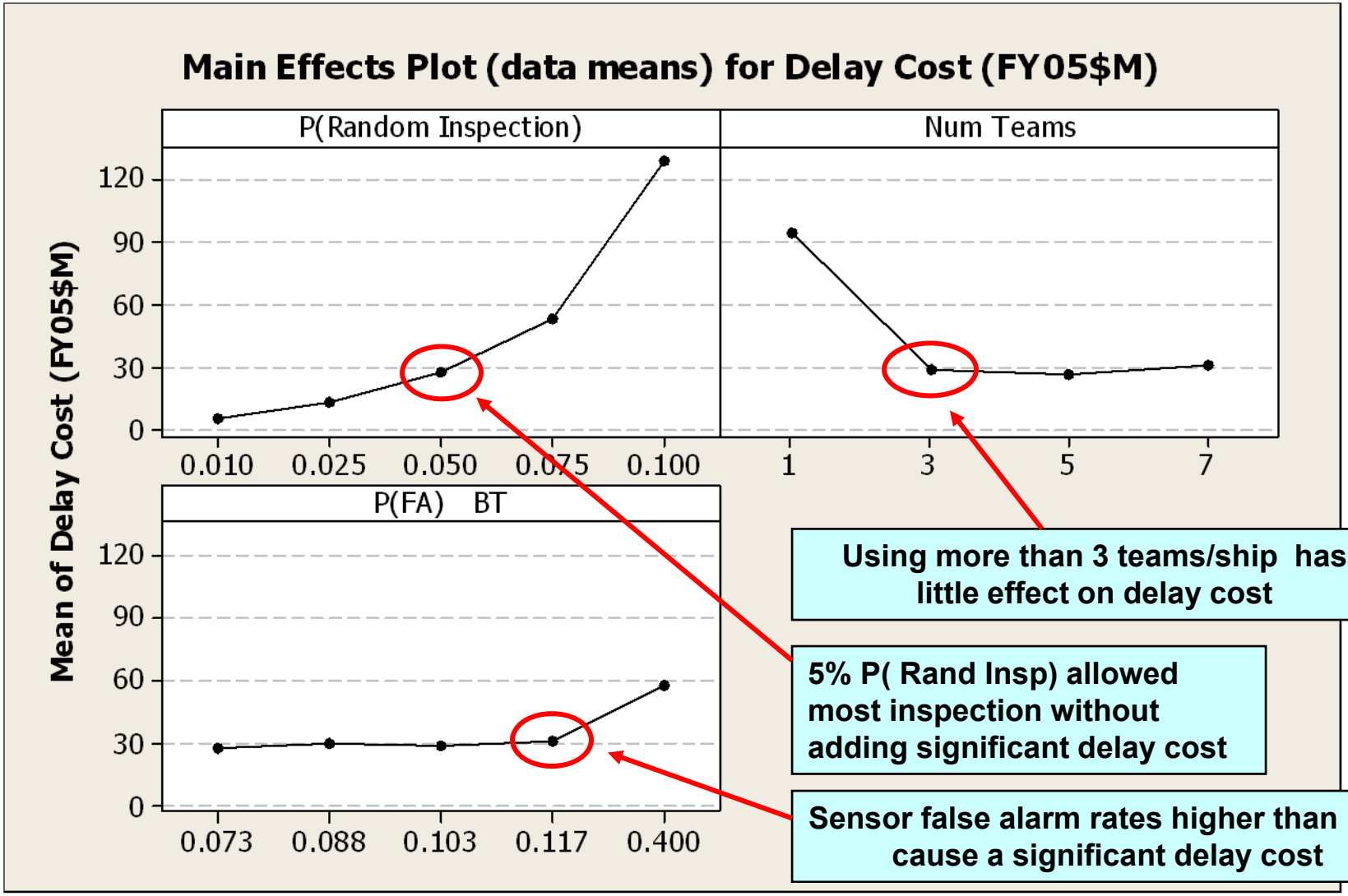
Sea Inspection Performance Model

→

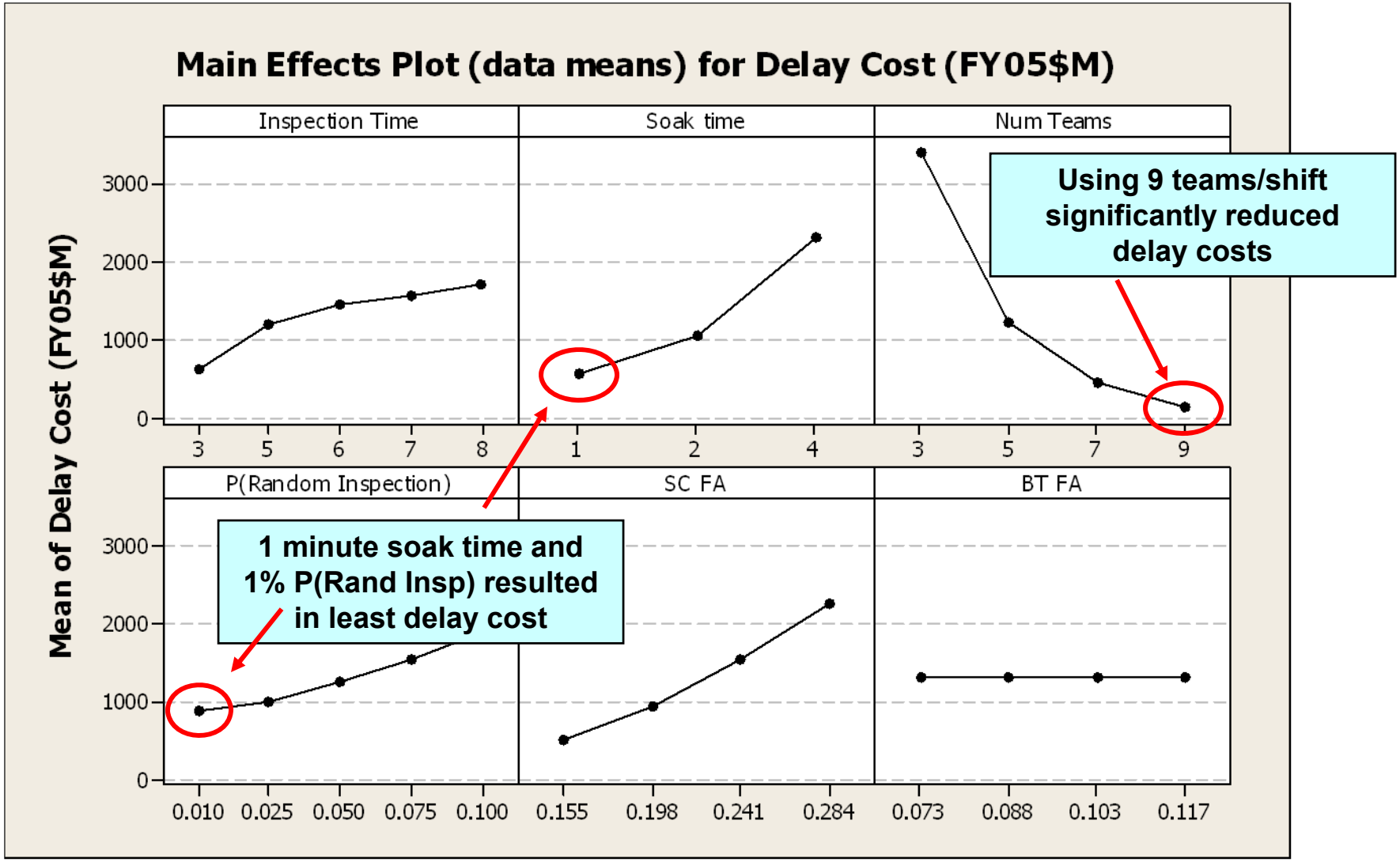
Outputs

- System P(d)
- System P(fa)
- % Ship Inspected
- Delay Time

Sea Inspection Alternative 1 Boarding Team Model Results



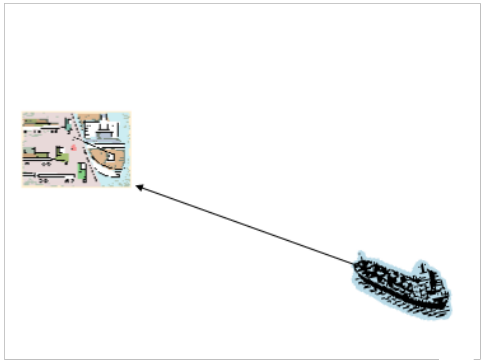
Sea Inspection Alternative 2 Honor System Model Results



Sea Inspection Model Parameters

			Values	
Factors		**Values**	**Alt 1 (BT)**	**Alt 2 (HONOR)**
Number of Teams		1,3,5,7,9	3	9
Inspection Time		3,5,6,7,8	7	8
Soak Time		1,2,4	1	1
P(Random Inspection)		1%, 2,5%, 5% , 7.5%, 10%	5%	1%
Shipwide P(FA) Smart Containers		0.155, 0.198, 0.241, 0.284	N/A	16%
Shipwide P(FA) Boarding Team		0.073, 0.088, 0.103, 0.107	12%	7%
Pd - Smart Containers	Neutron	0.5, 0.8	N/A	80%
	Gamma	0.6, 0.7	N/A	70%
	Chem/Bio	0.3, 0.4	N/A	40%
	Explosive	0.1, 0.2	N/A	20%
Pd - Boarding Team	Neutron	0.1, 0.25	25%	25%
	Gamma	0.1, 0.25	25%	25%
	Chem/Bio	0.2, 0.3	30%	30%
	Explosive	0.4, 0.5	50%	50%

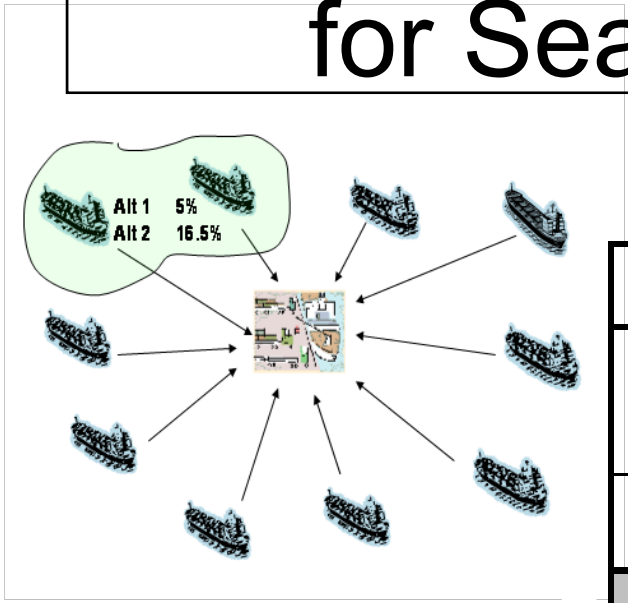
Sea Inspection Model Results for Single Ship



MOE / Metrics	'As-Is'	ALT 1	ALT 2
Percent Cargo Inspected	0%	100%	100%
P(Detect | Inspect)	0%	25%	25%
P(Detect) WMD on Ship	0%	25%	25%
Comm. Delay Cost ($M)	0	.01	.02
Comm. Cost ($M)	0	0	10
MDP System Cost ($M)	0	17	100
Total System Cost ($M)	0	17	110

* All costs cover 10-year time period

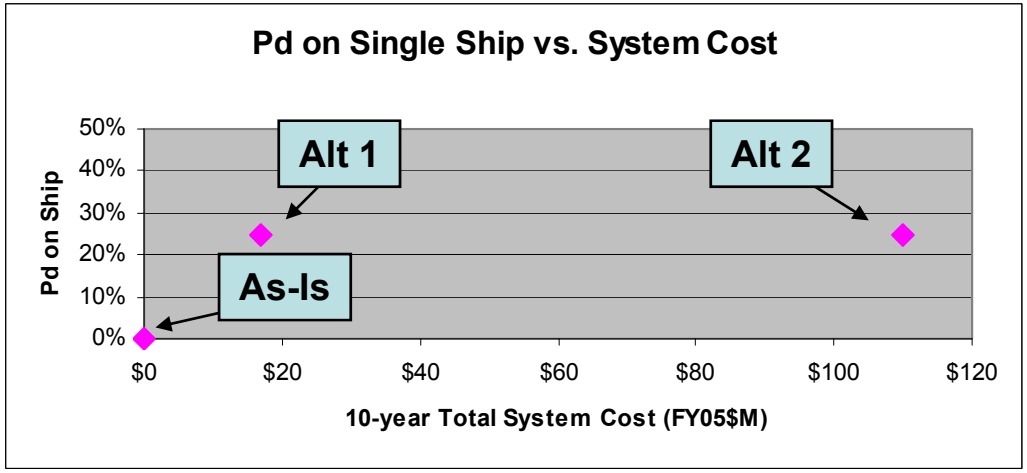
Sea Inspection Model Results for Sea Inspection System

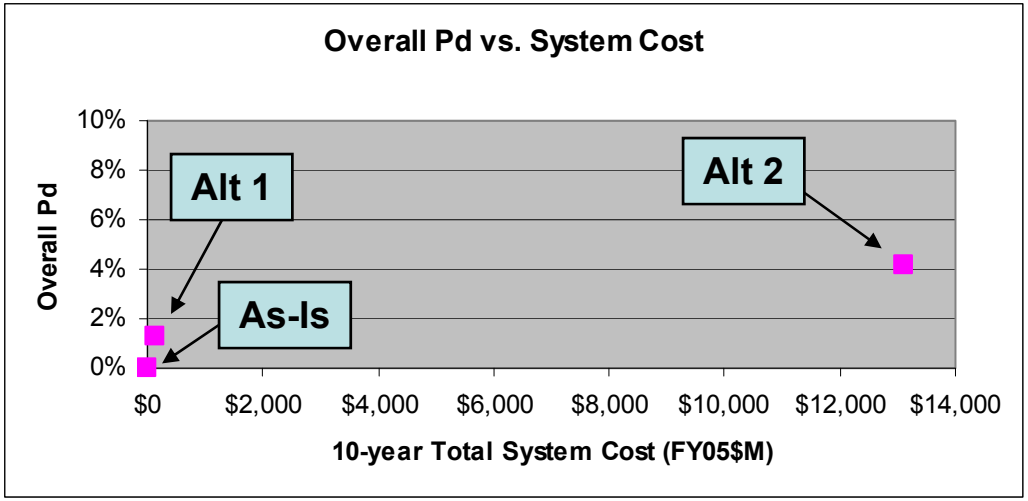


MOE / Metrics	'As-Is'	ALT 1	ALT 2
% Inbound Ships Inspected	0%	5%	16.5%
P(Detect) WMD on Ship	0%	25%	25%
Overall Pd WMD Inbound	0%	1.2%	4.1%
Comm. Delay Cost ($M)	0	130	330
Comm. Cost ($M)	0	0	12,680
MDP System Cost ($M)	0	17	100
Total System Cost ($M)	0	147	13,110

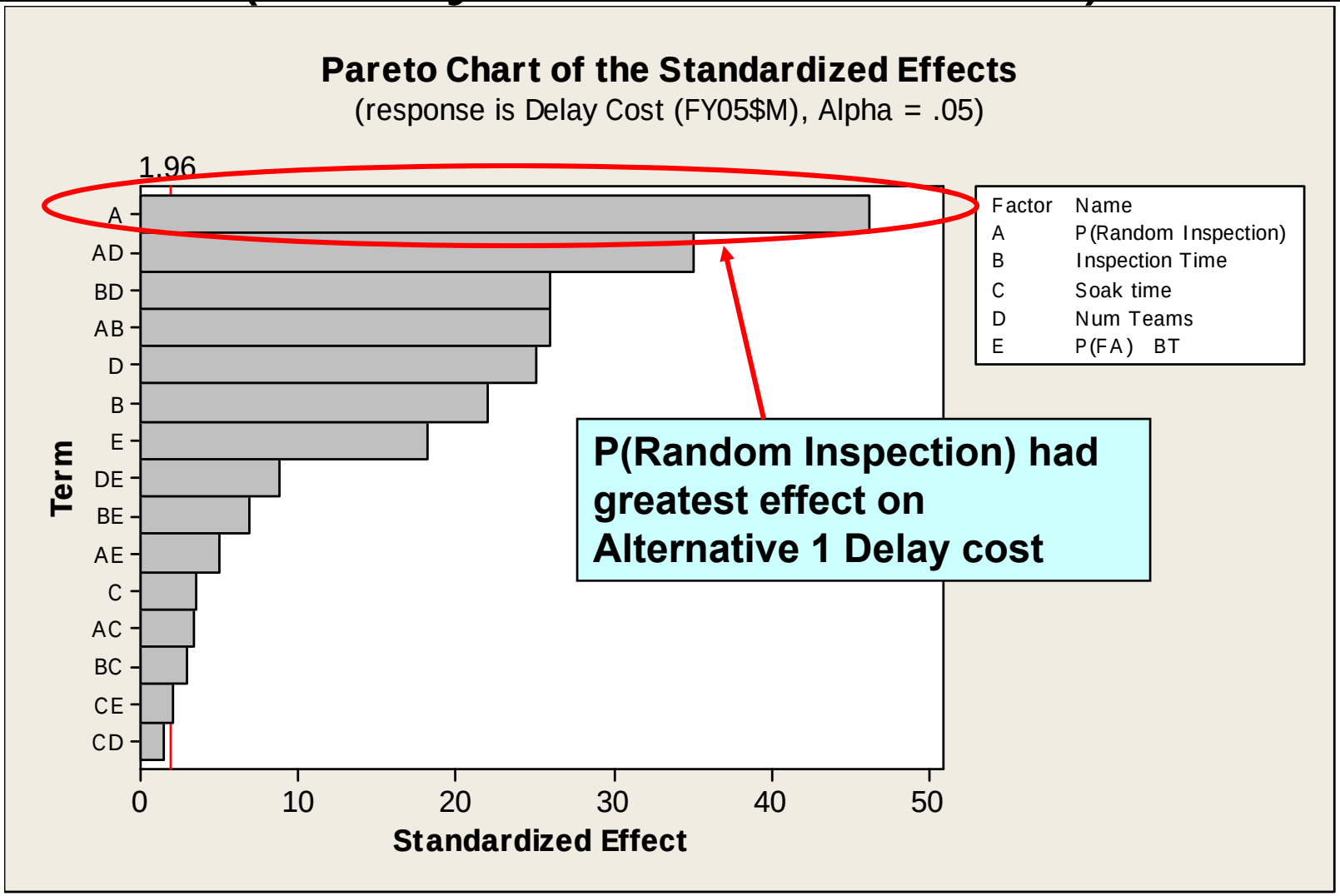
* All costs cover 10-year time period

Sea Inspection Model Results

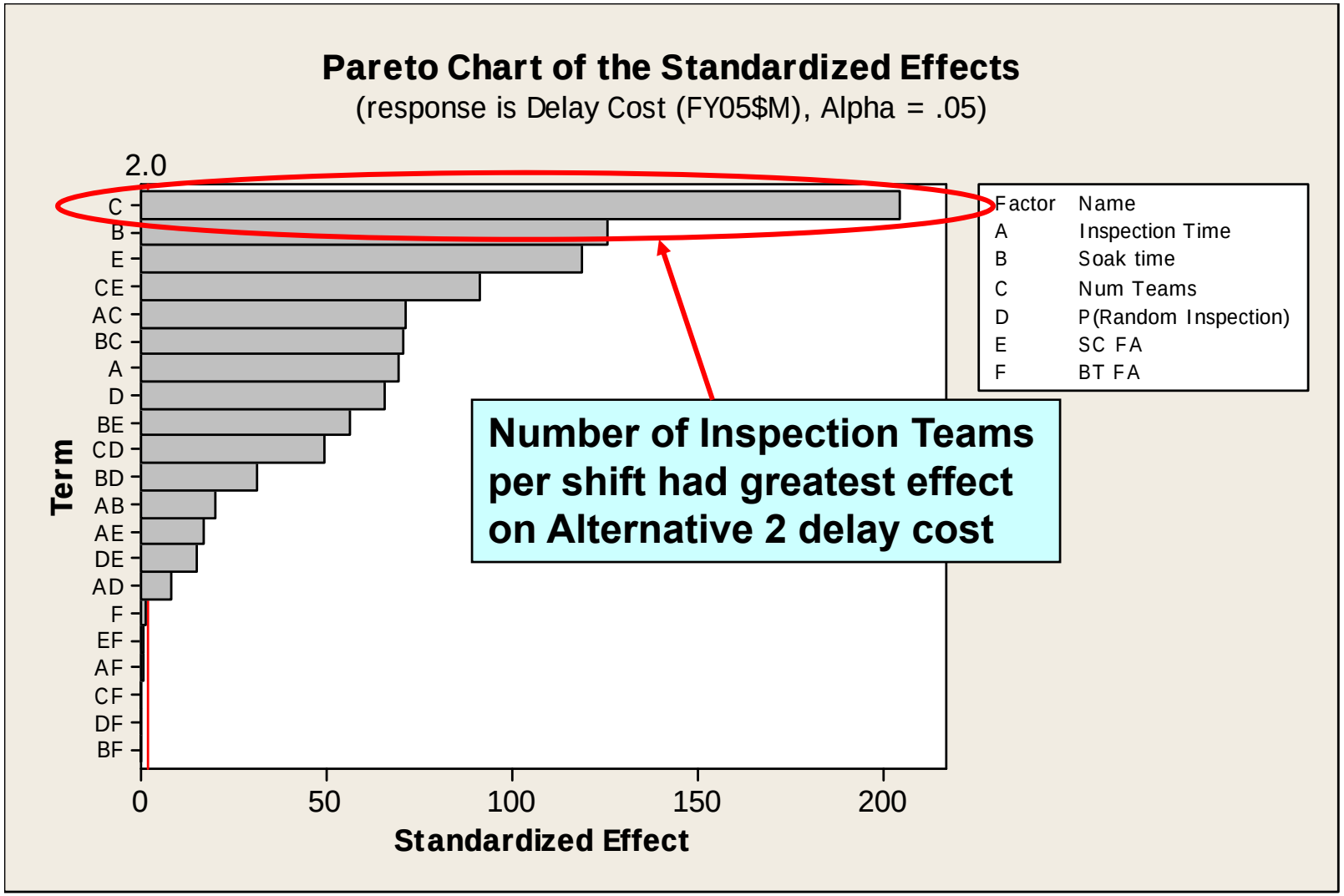




Pareto Chart of Effects (Delay – Alternative 1)



Pareto Chart of Effects (Delay – Alternative 2)



Sea Inspection Conclusions/Insights

- Enroute at-sea cargo inspections can be effective using current sensor technology, but effective C3I is required
- Smart Container benefits possible, but at great expense
- # Teams/shift, P(Random Inspection) and Soak Time had greatest effect on system performance and delay cost
- Deterrence factor of boarding teams may justify cost of boarding teams

RECOMMENDATIONS

- Continue development of sensor technologies to increase P(d)
- Money would be best spent on increasing #Teams/shift to minimize delay cost
- Develop algorithm for AIS data to augment the inspection selection process
- Develop sensor mapping feature of SMART container devices to localize anomalies more accurately

TDSI: Land Systems Integration

- Objective
- Assumptions
- Search Model
- Results
- Conclusions

Objective

- To determine search parameters for input to the Sea Inspection Model for the efficient search of container ships using portable detection systems.

Assumptions

- Focus on search strategies
  - Ship-board human search
  - Ship-board robotic system as an alternative
  - Search strategies matched with detector capabilities
- Performance of inspection entities and detectors
  - Not an “As-Is” systems; capability not proven
  - Search capability of robotic platforms assumed
- Real-life search times may vary
  - Lack of precise performance specs of detectors

Search Model

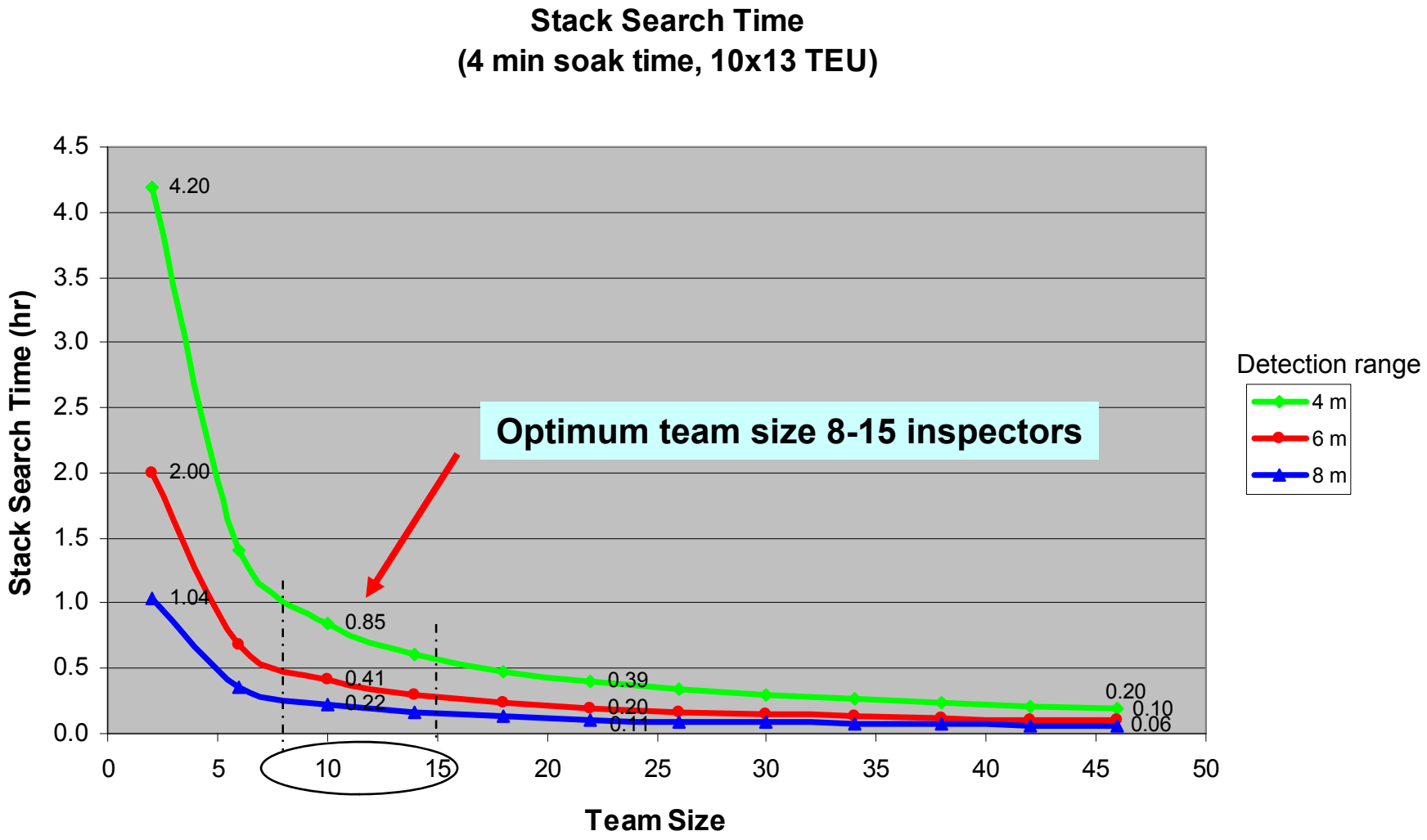
- Search environment
  - Large container ships
    - ~ 4000 to 8000 TEUs
  - Containers: 20 ft x 8.5 ft x 8 ft
- Search entity
  - Human with portable equipment
    - Deck search 6 containers/min
    - Stack search 1.8 containers/min
- Detector
  - Passive Gamma Ray detector (portable germanium detector)
  - Excel model to calculate detection distance for U235 @ 186keV and Pu239 @ 414keV
  - Can detect **25kg HEU** with ¼ **“ lead shielding** at **4.2m**
  - 1, 2 or 4 min soak time

Search Model

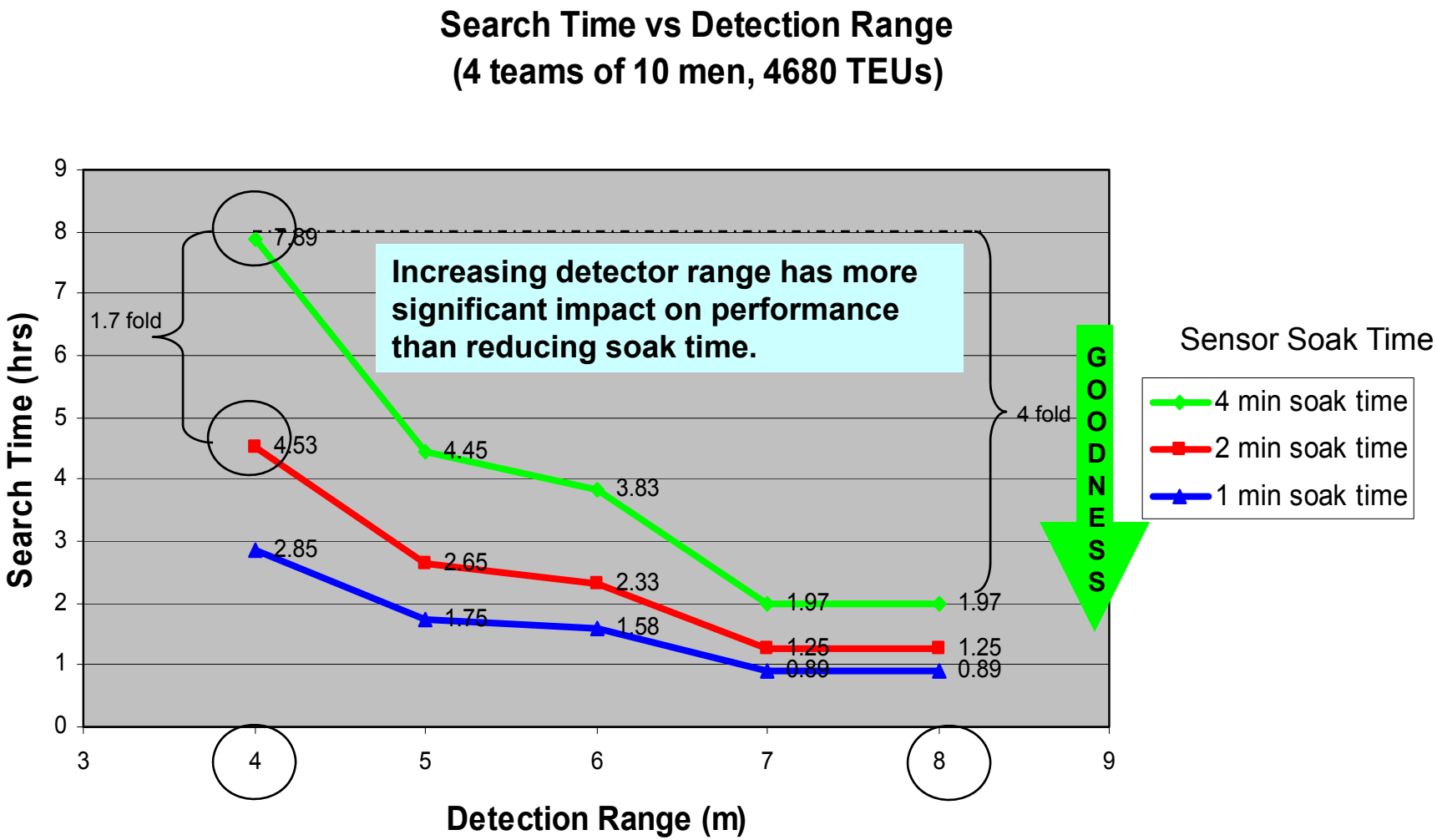
- Search parameters
  - Detector soak time
  - Detection range
  - Number of search entities
  - Container vessel size
  - Container stacking configuration

- MOP: Search time for container stack(s)

Results: Variation of stack search time with team size

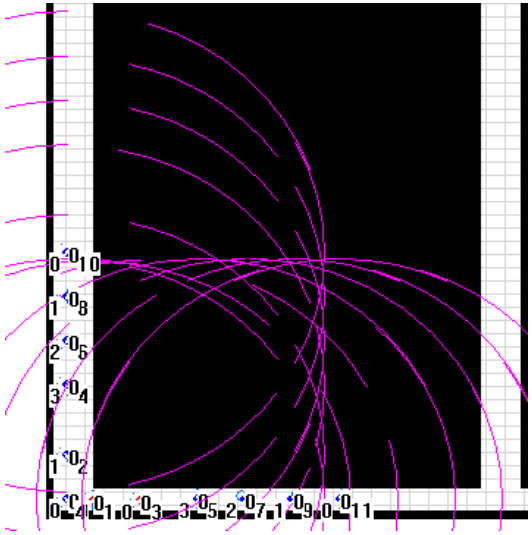


Results: Variation of search time with detection range and soak time

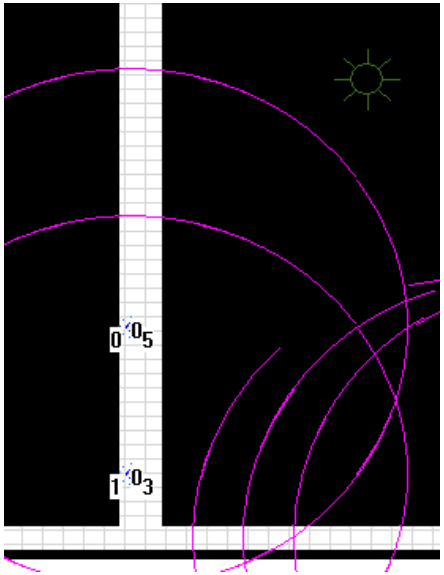


Autonomous systems: Basic Robotic Behaviors

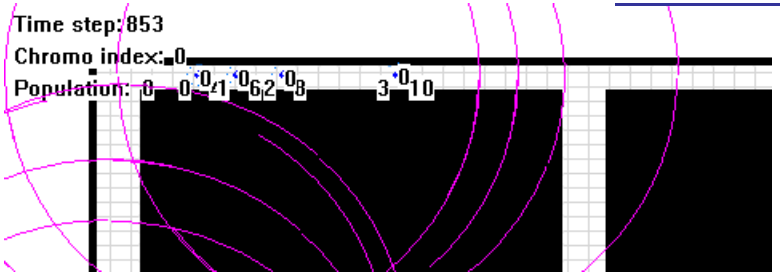
- In order of decision priority levels:
  - Obstacle Avoidance
  - Dispersion
    - When density of robots scanning target sources gets large
    - When density of robots in vicinity gets large
  - Sense & Scan
  - Trail Marking Monitoring
    - Turn away when trail marking counter for route ahead is higher or when current counter is high
    - ELSE proceed as normal if current trail marking counter is much higher than the one ahead



Dispersion

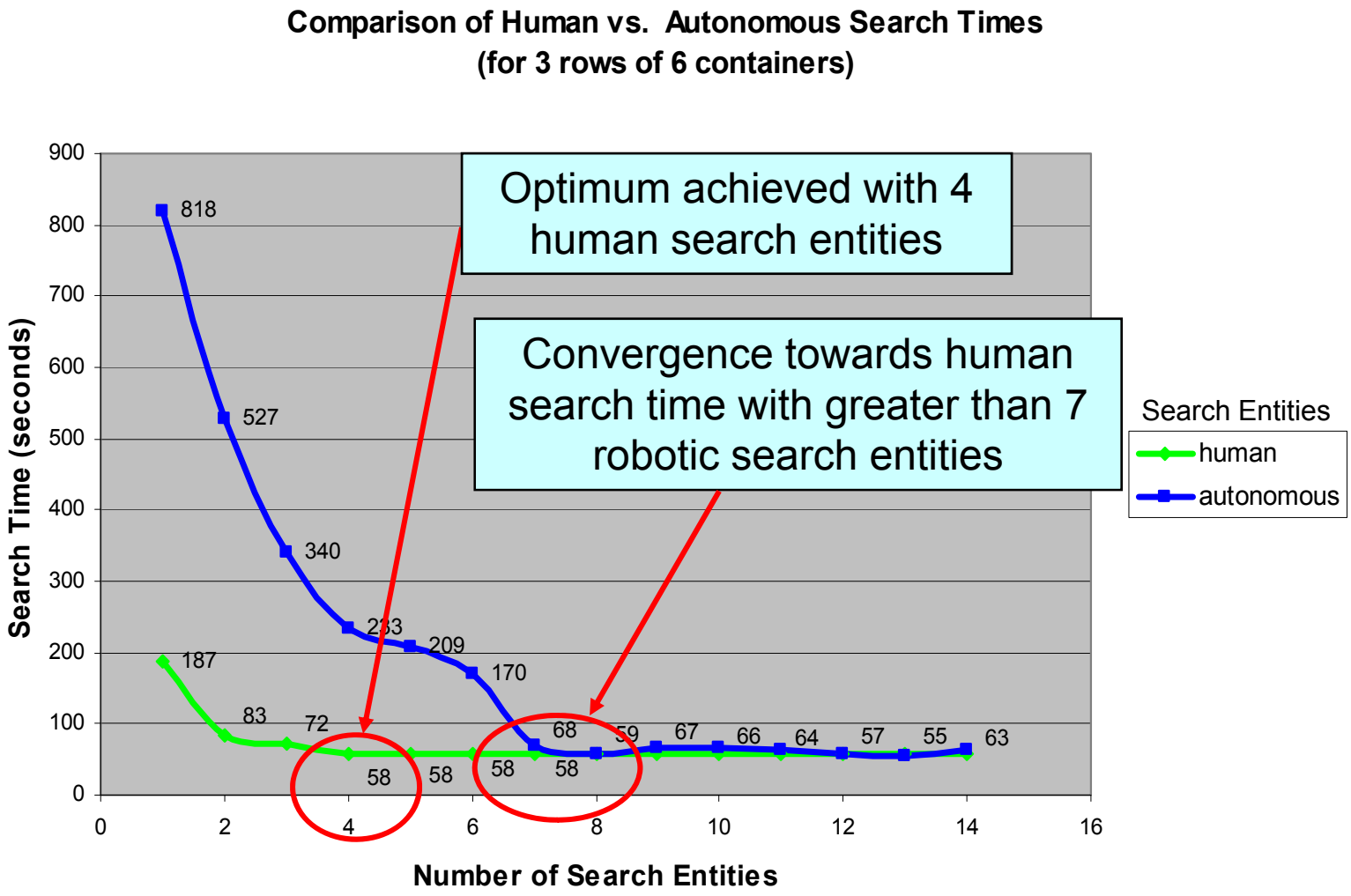


Sense & Scan



Trail Marking

Model results



Conclusions

- Optimum team size is 8-15
- Parameters of significance:
  - Soak Time
  - Detection Range
- Performance
  - Coordinated human search strategy outperforms autonomous search algorithm modeled

Questions?

Sea Inspection Group

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LT Matt Wiens

LT Shannon Hoffmann

LT Tracey Crider

TDSI Land Inspection Group

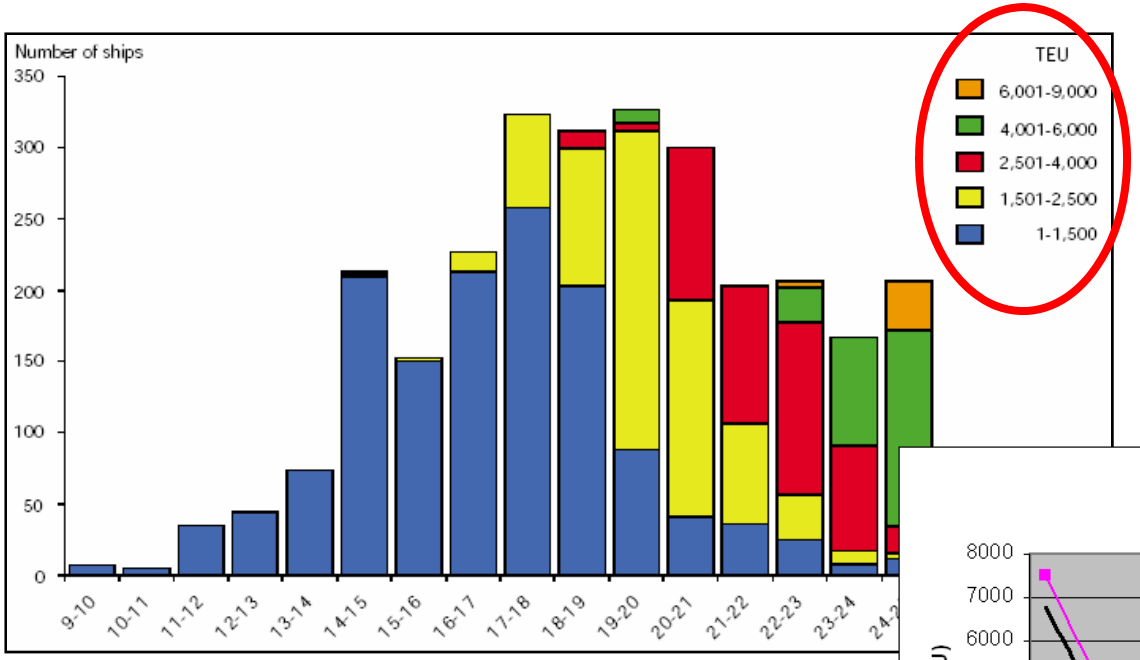
MAJ Wee Tuan Khoo

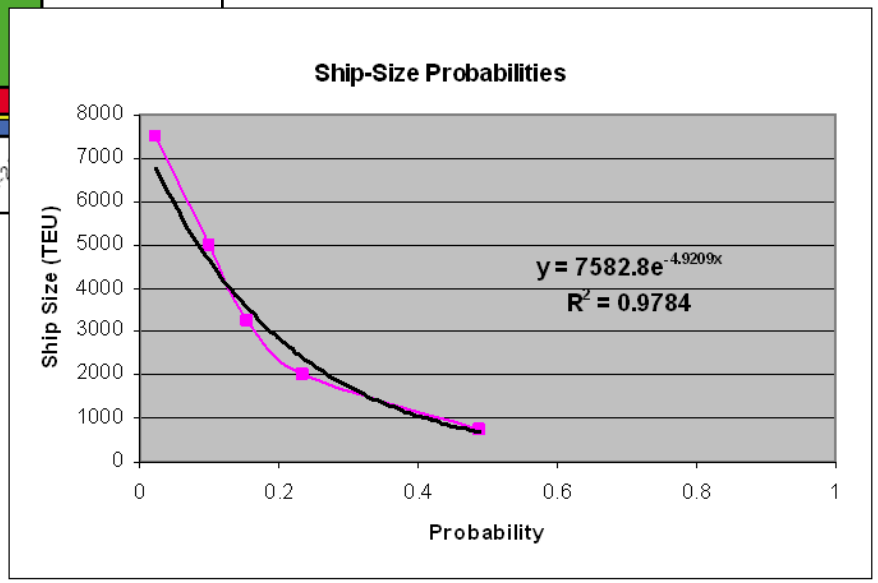
CPT Joel Lim

CPT Alan Yeoh

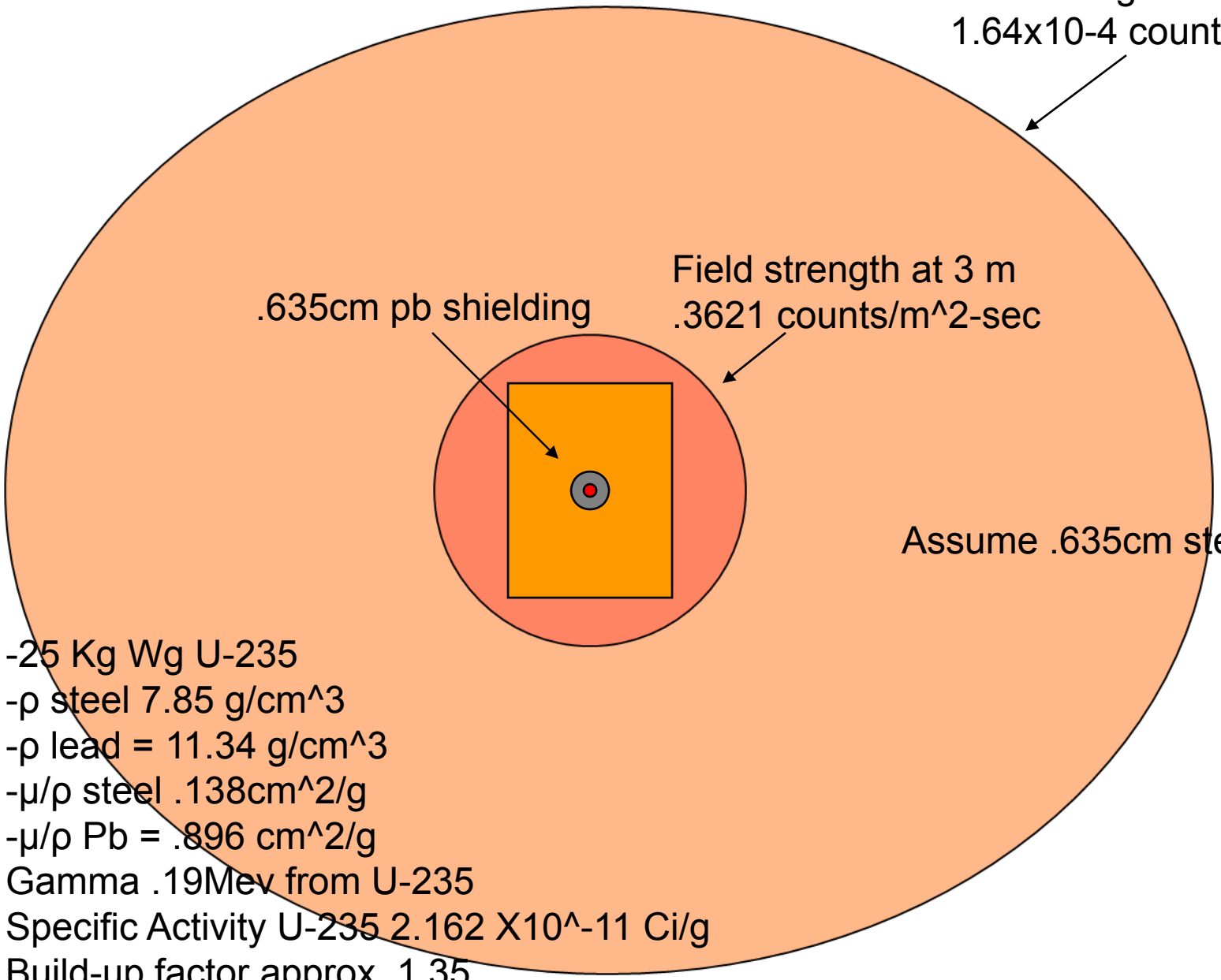
Back-Up Slides

Back-Up


Number of ships
350
300
250
200
150
100
50
0
9-10
10-11
11-12
12-13
13-14
14-15
15-16
16-17
17-18
18-19
19-20
20-21
21-22
22-23
23-24
TEU
6,001-9,000
4,001-6,000
2,501-4,000
1,501-2,500
1-1,500

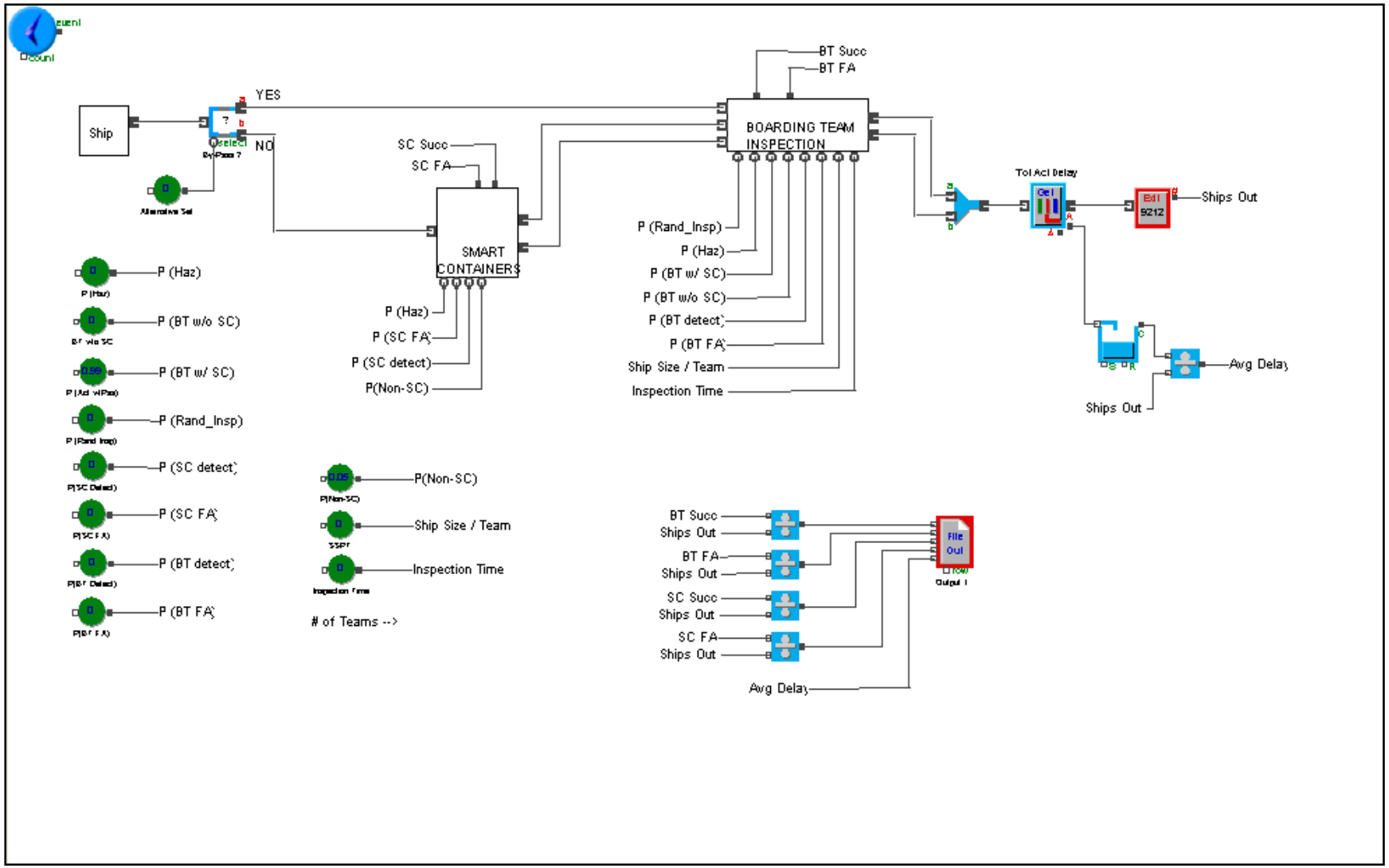

Ship-Size Probabilities
Ship Size (TEU)
8000
7000
6000
5000
4000
3000
2000
1000
0
0
0.2
0.4
0.6
0.8
1
Probability
y = 7582.8e^-4.9209x
R^2 = 0.9784

½ inch Pb shielding

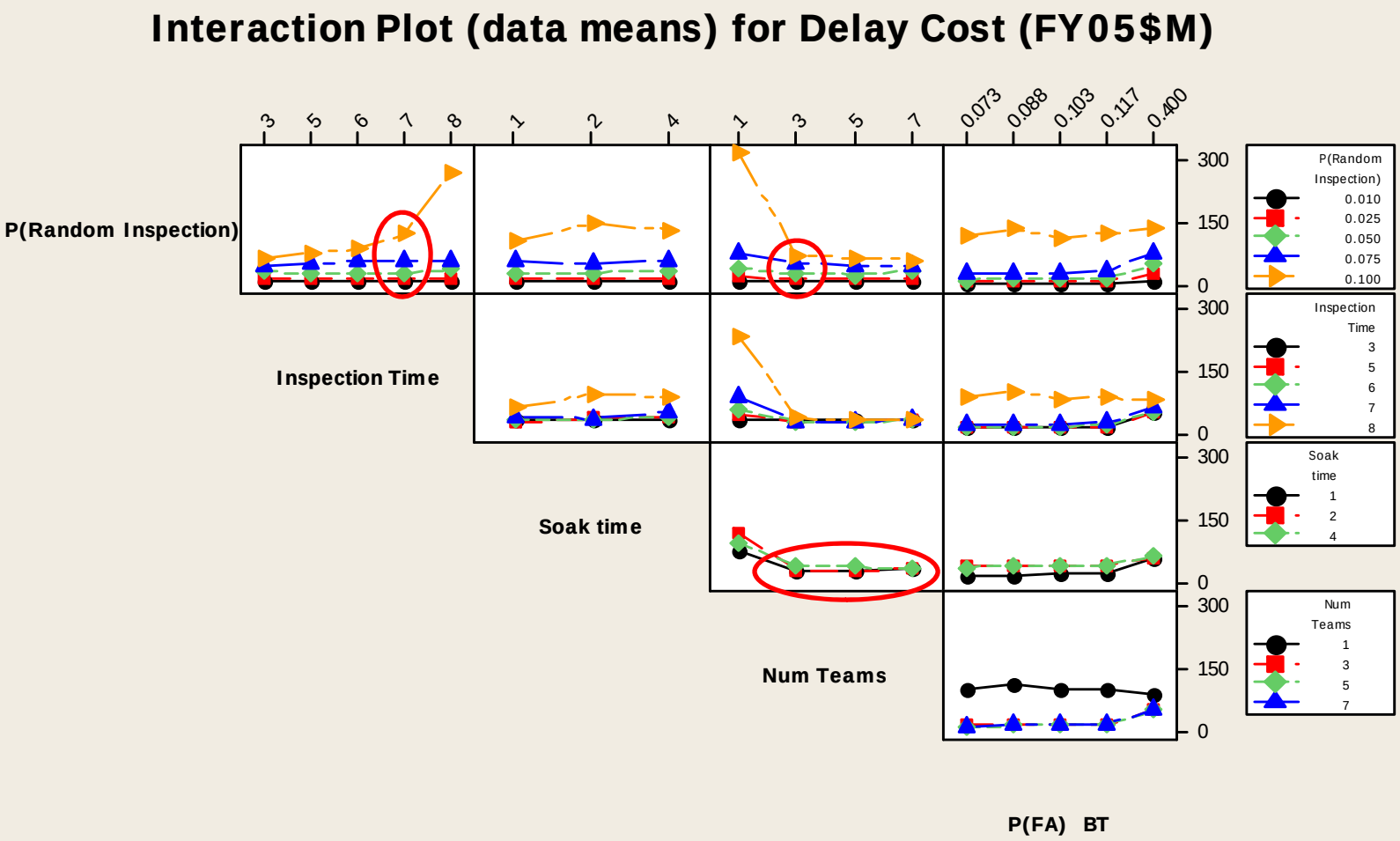


-25 Kg Wg U-235
-ρ steel 7.85 g/cm^3
-ρ lead = 11.34 g/cm^3
-μ/ρ steel .138cm^2/g
-μ/ρ Pb = .896 cm^2/g
Gamma .19Mev from U-235
Specific Activity U-235 2.162 X10^-11 Ci/g
Build-up factor approx. 1.35

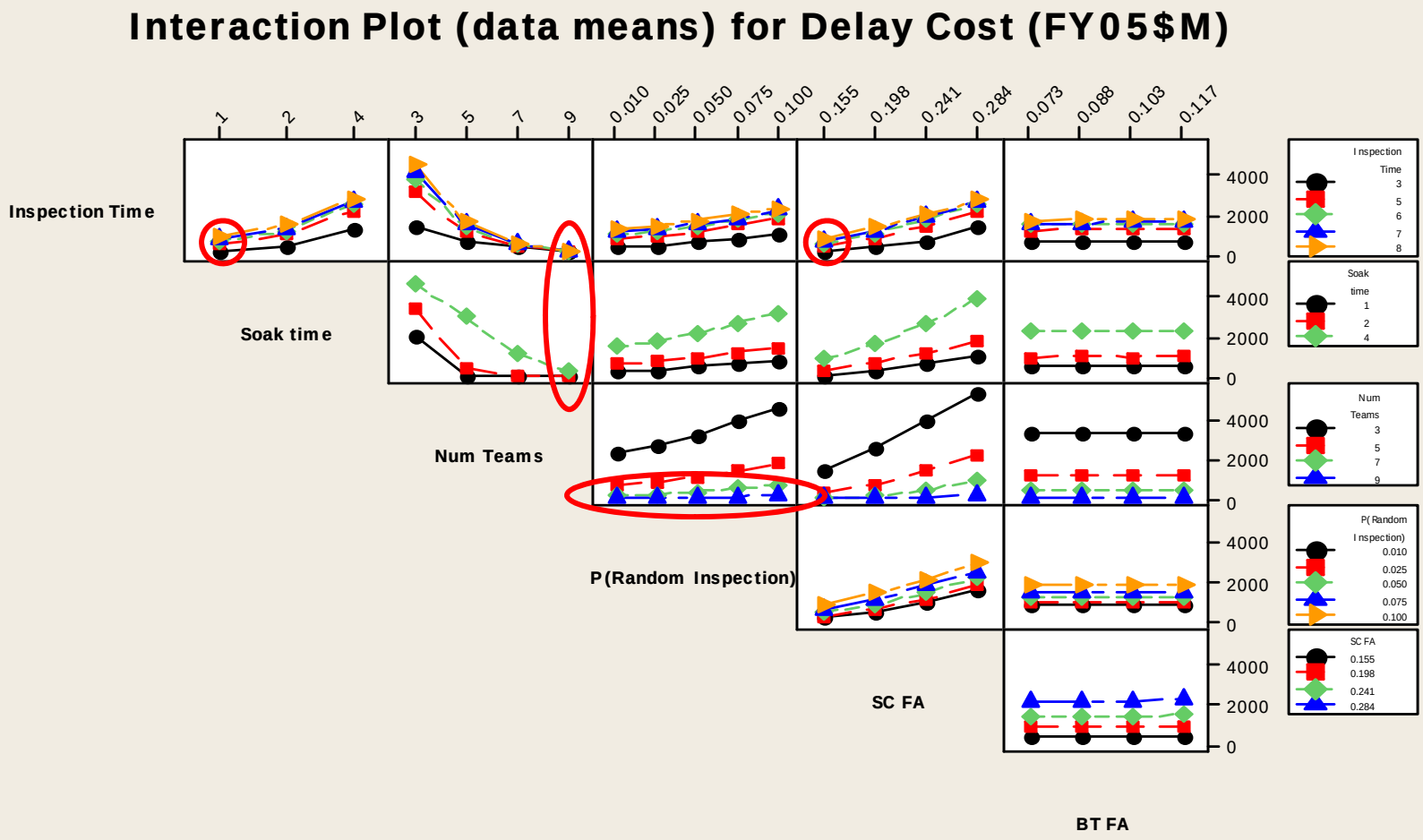
Sea Inspection Model Overview



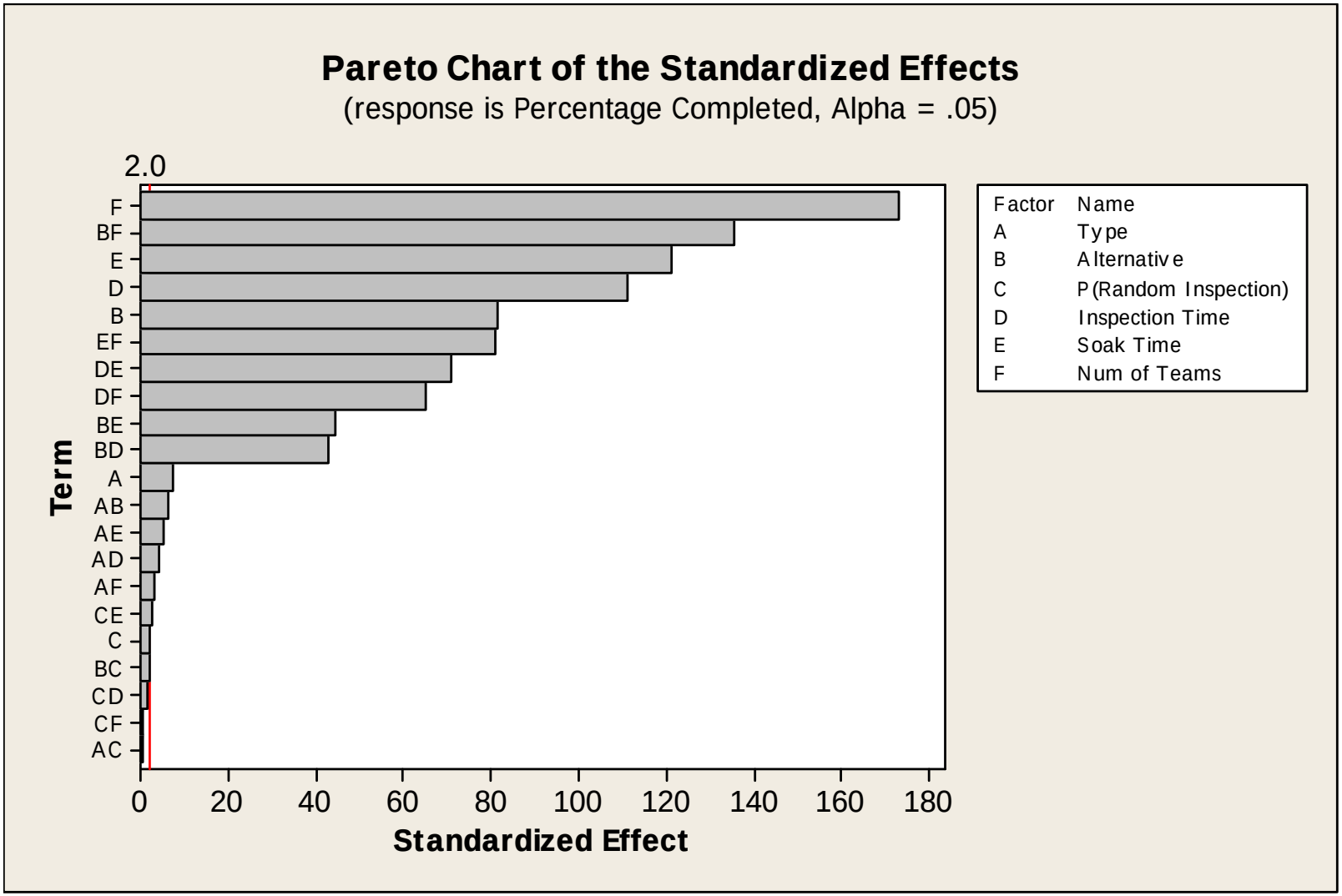
Alternative 1
Boarding Team Results



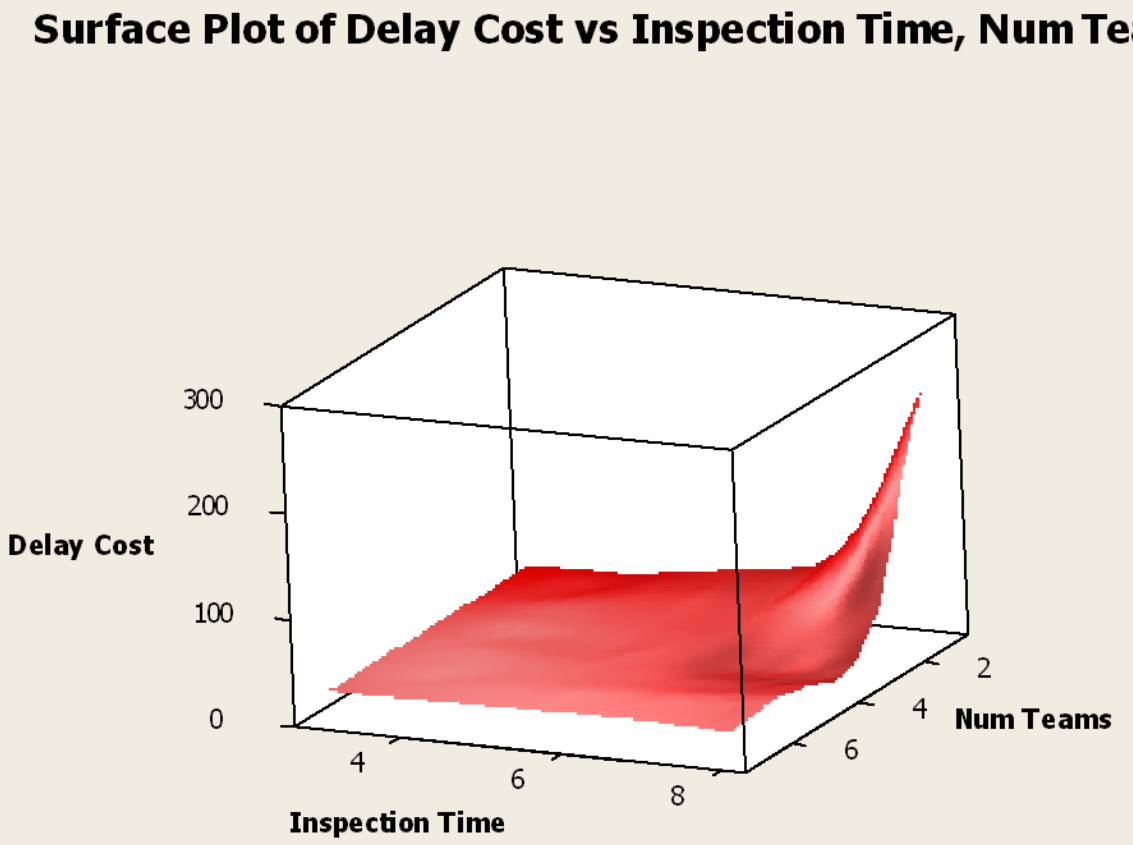
Alternative 2
Honor System Results



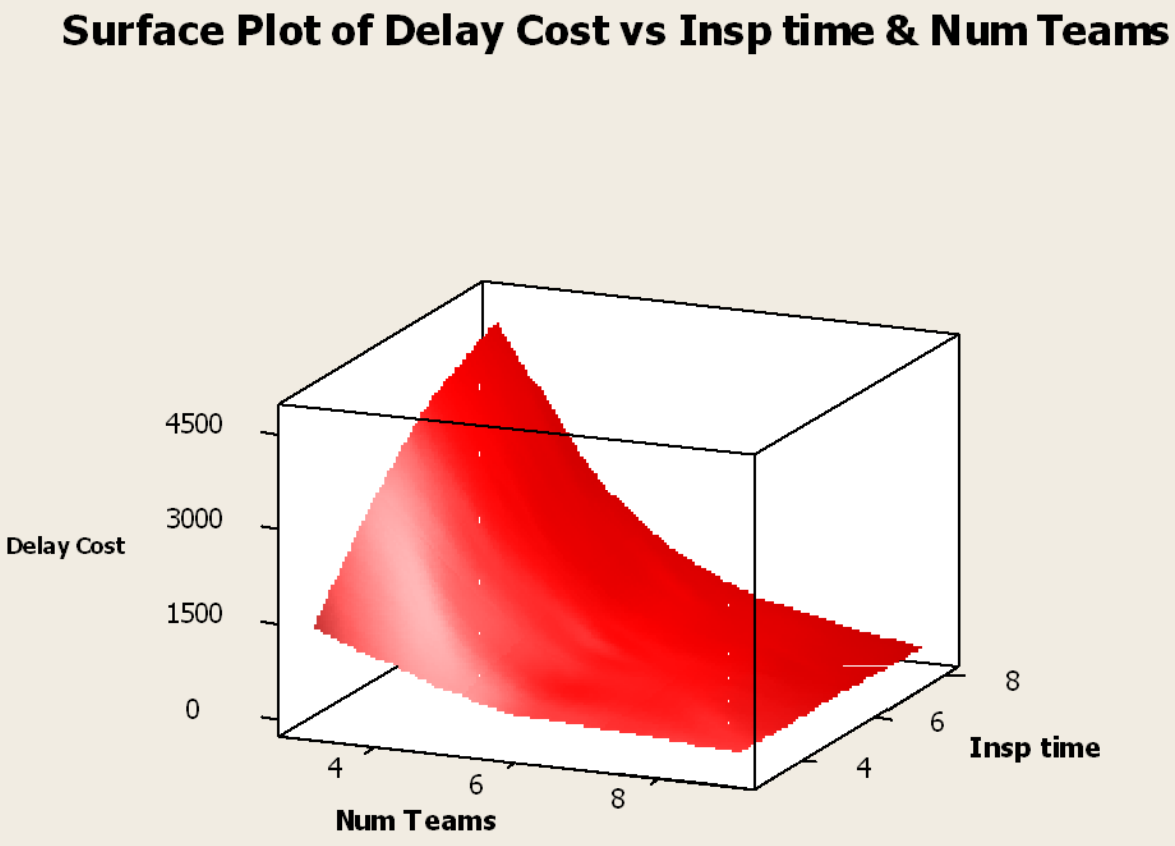
Pareto Chart of Effects (Performance)



Alternative 1
Delay Cost vs. Inspection Time & # Teams

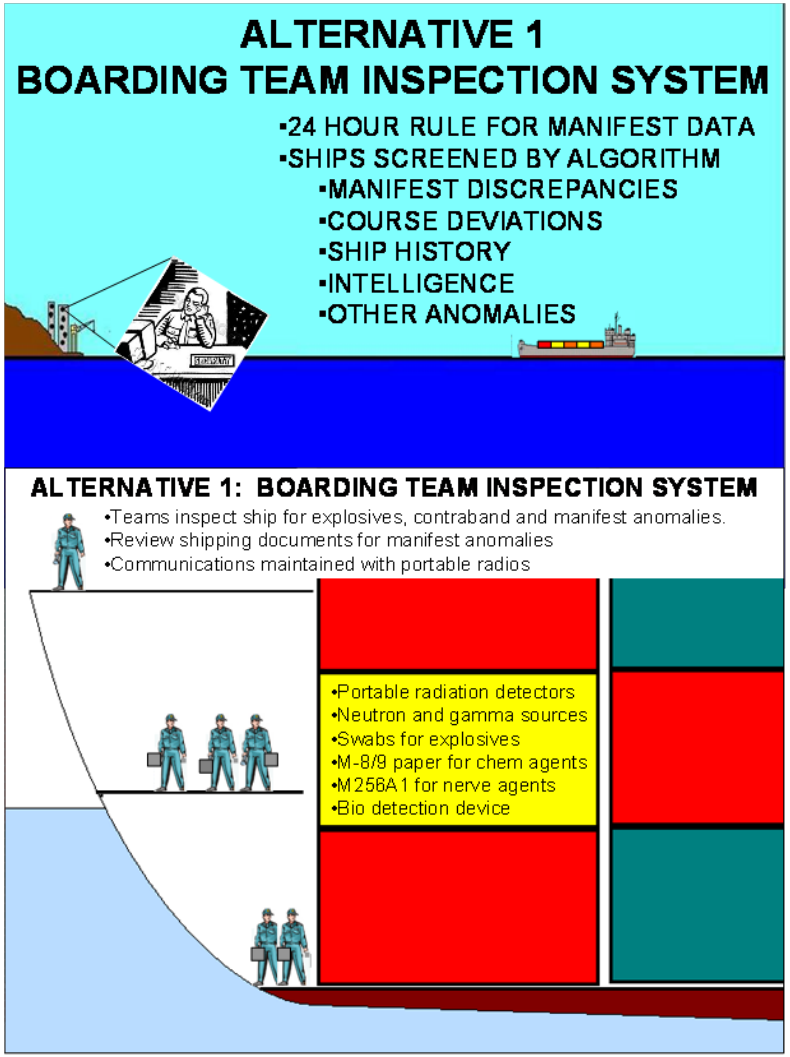


Alternative 2
Delay Cost vs. Inspection Time & # Teams

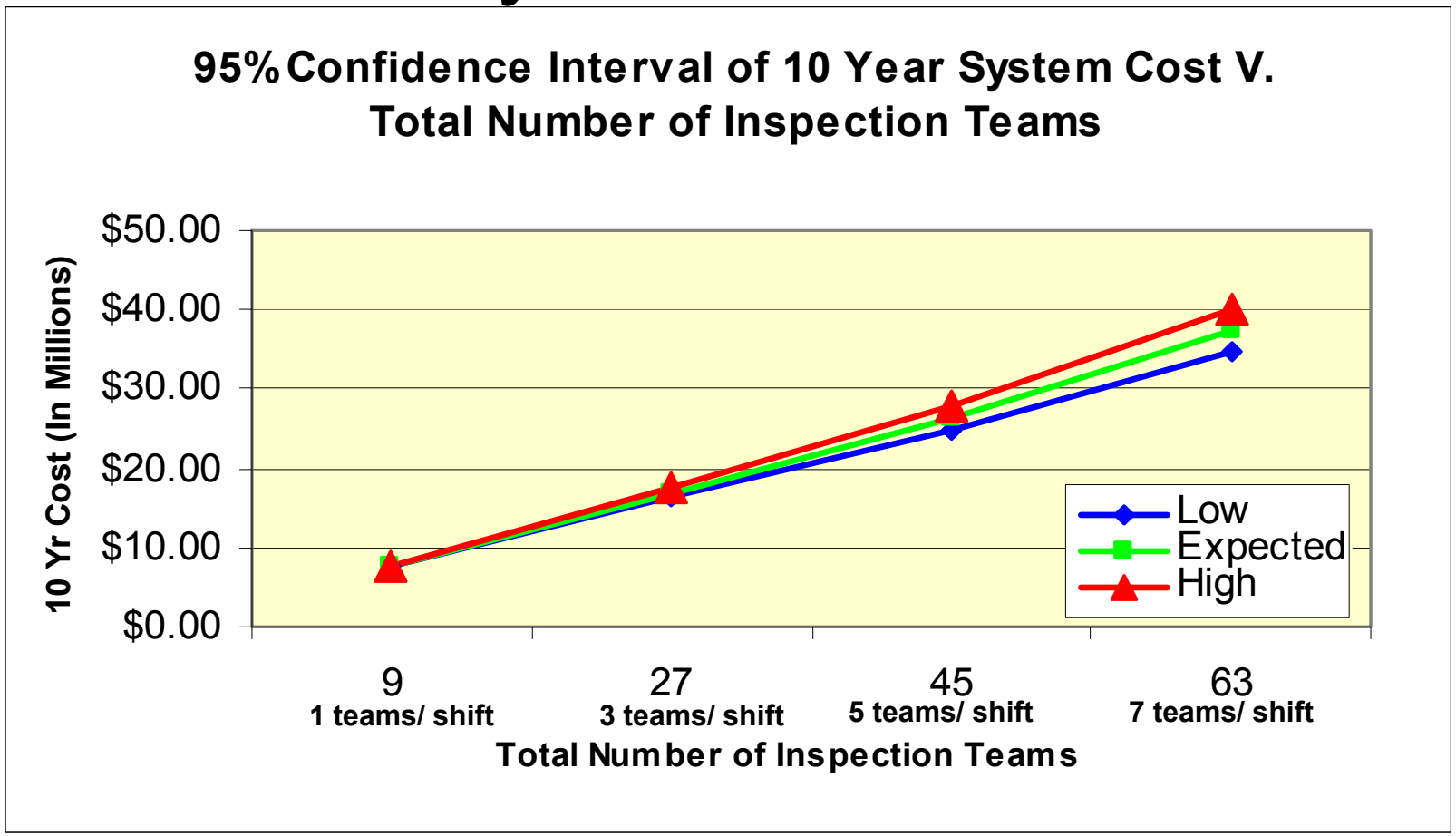


Alternative 1
Boarding Team Model Results

- **Performance**
  - Pd - 25%
  - Average Delay Time
    - 0.21 hrs/ship
  - Ave Percent Inspected
    - 100%
- **Cost**
  - System Cost
    - $16.93M (3 Teams/Shift)
  - Commercial Cost
    - $0
  - Ave Delay Cost
    - $13.17M



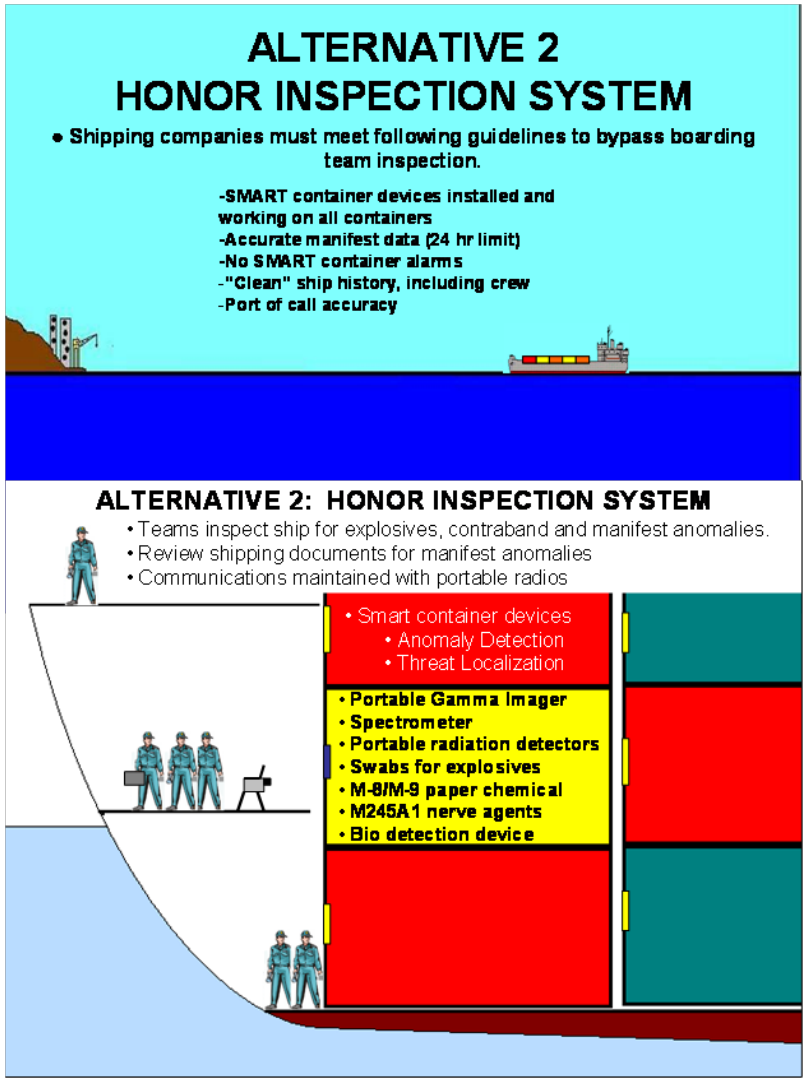
Alternative 1
Boarding Team Model Results
System Costs



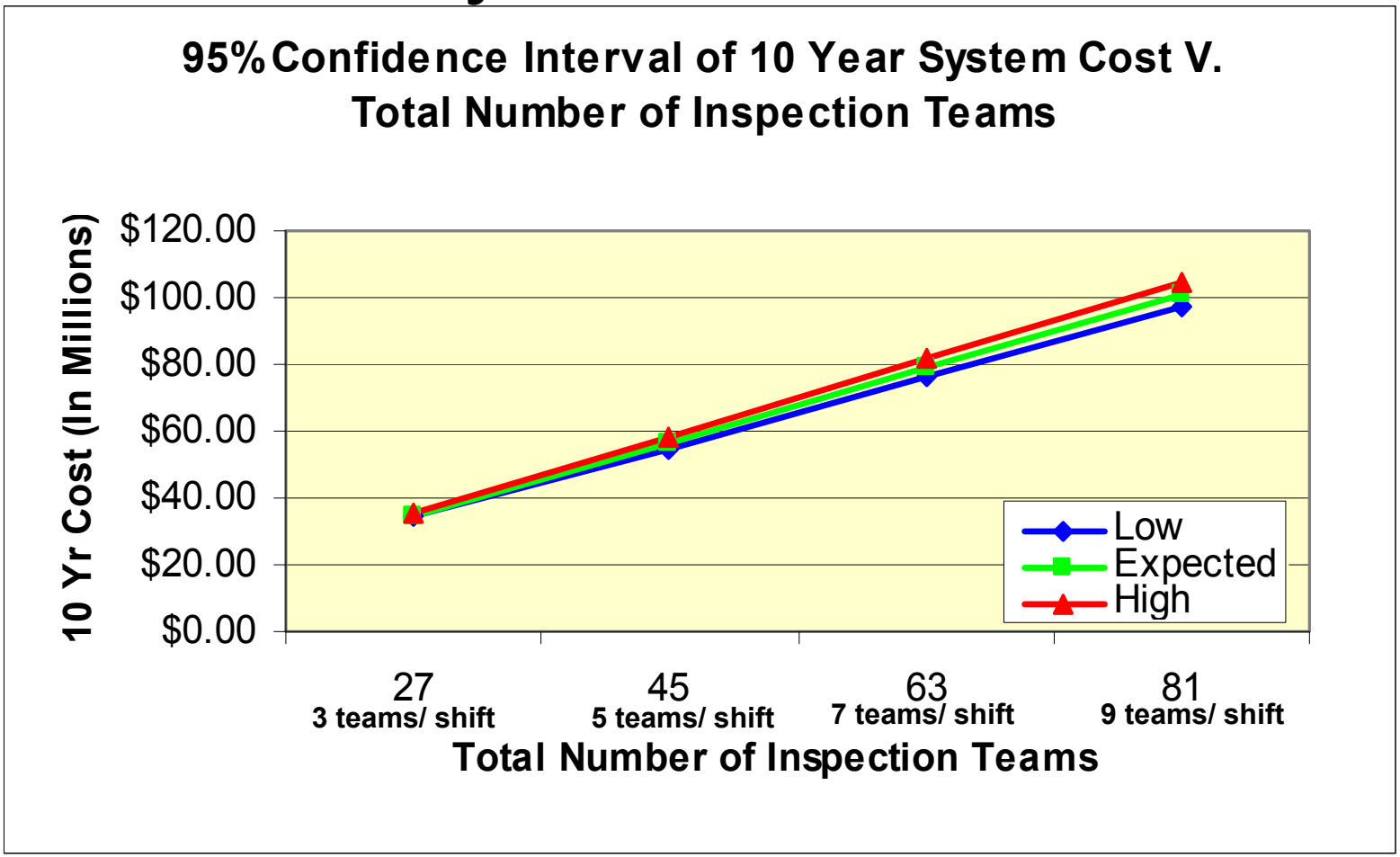
ALL COSTS ARE IN FY05$

Alternative 2
Honor System Model Results

- **Performance**
  - Pd - 66.41% (SC)
  - Pd - 24.18% (BT)
  - Average Delay Time
    - 0.53 hrs/ship
  - Ave Percent Inspected
    - 100%
- **Cost**
  - System Cost
    - $100M (9 Teams/Shift)
  - Commercial Cost
    - $12.68B
  - Average Delay Cost
    - $32.69M/ship-year

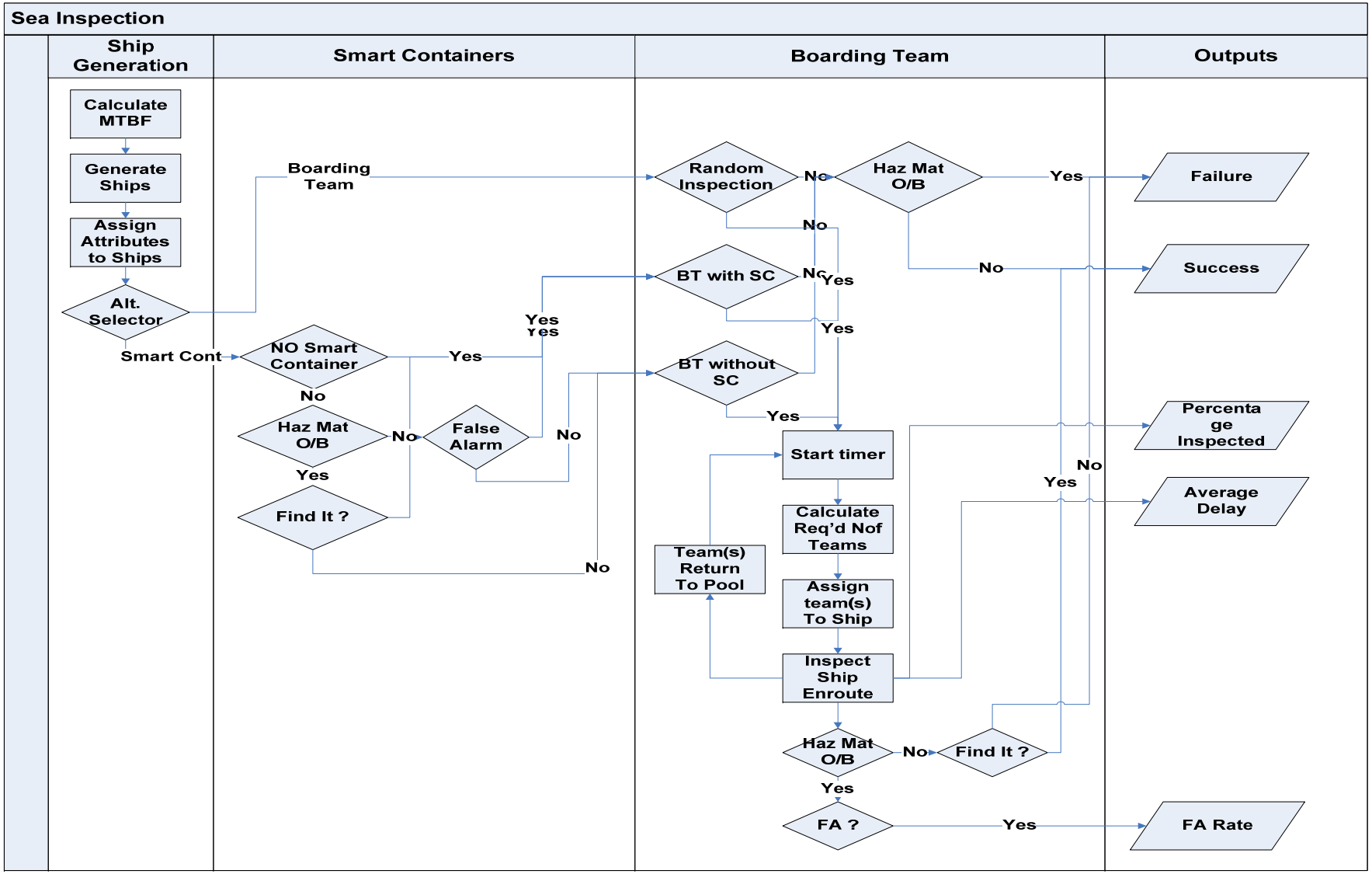


Alternative 2
Honor System Model Results
System Costs

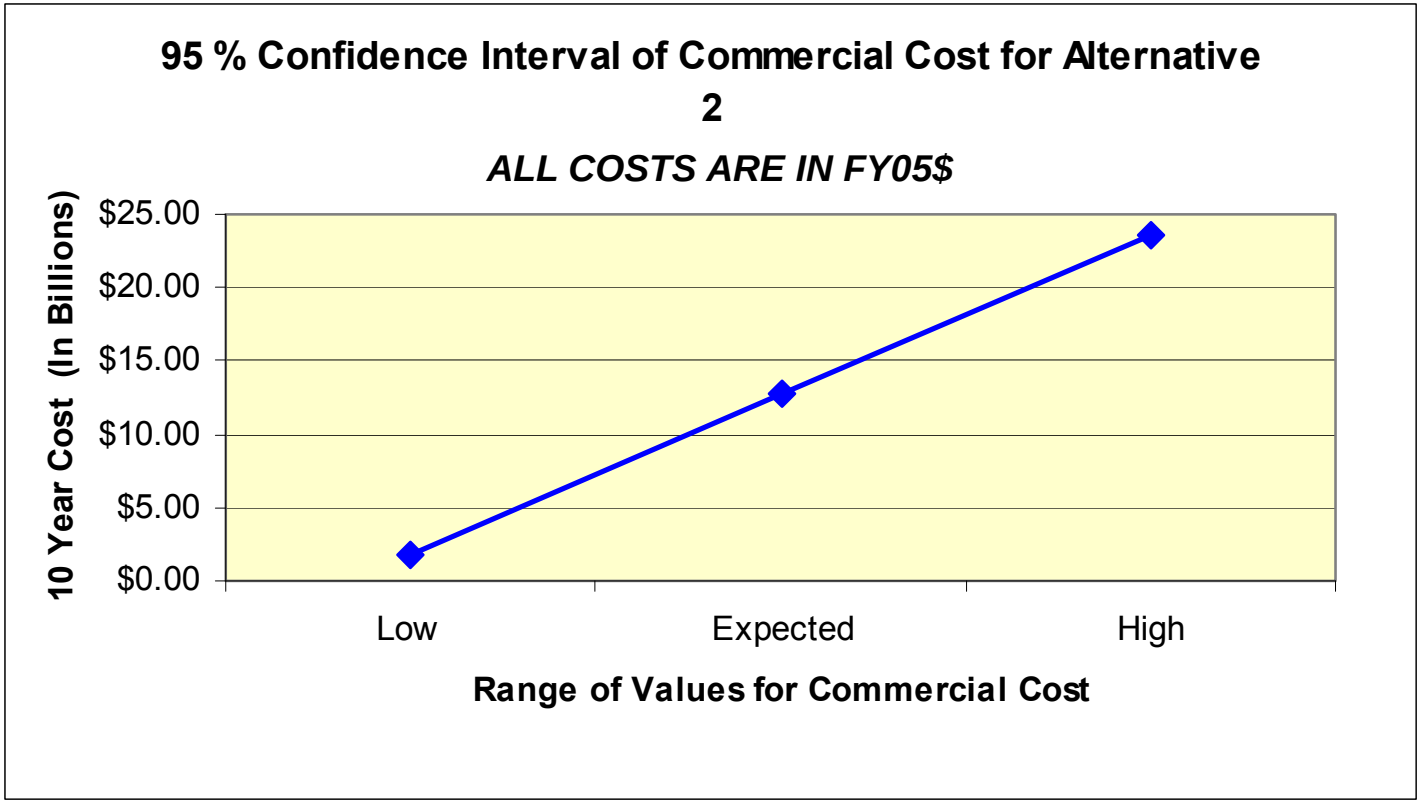


ALL COSTS ARE IN FY05$

Model Flow Chart



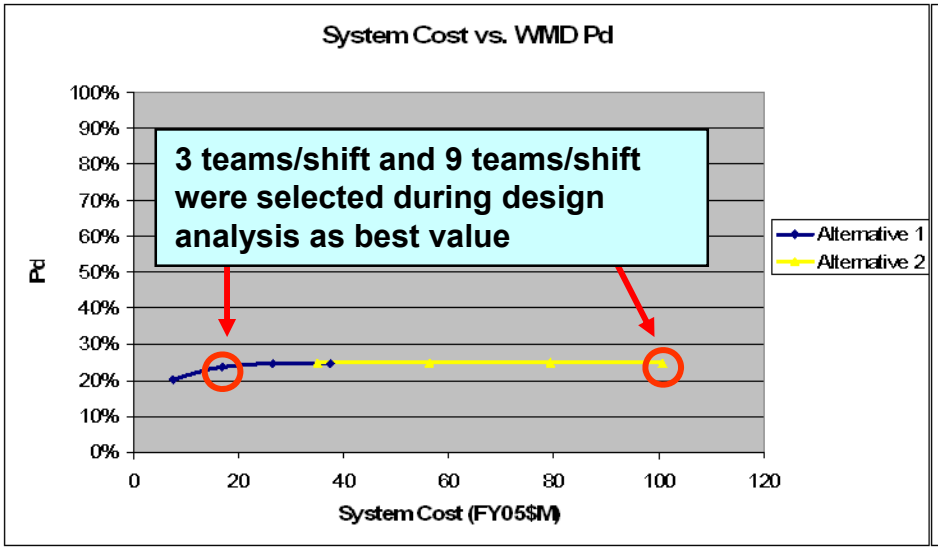
Honor System Model Results
Commercial Costs

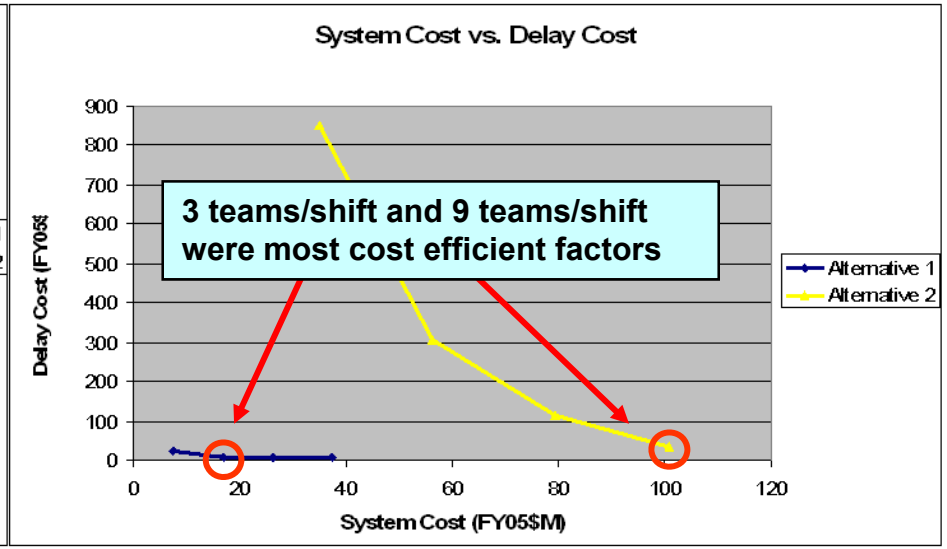


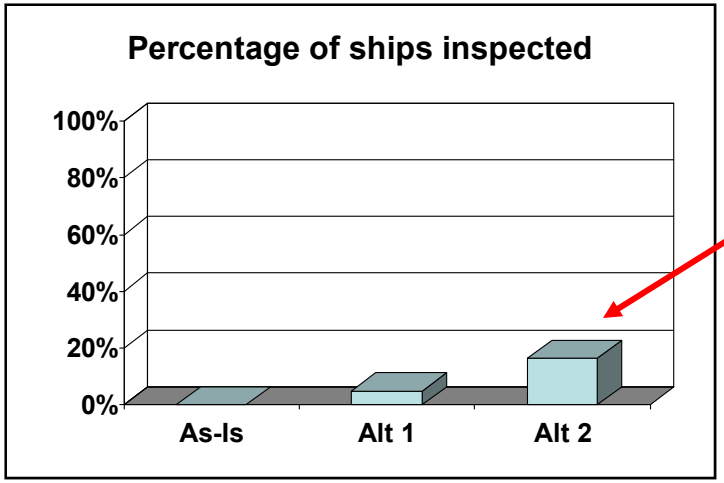
Note: Commercial Costs will remain the same for all team sizes. Cost is a factor of how many SMART containers are implemented each year. For the model, it was assumed that all shipping containers would have the SMART container technology within the first year and a 5% replacement each year thereafter.

95% Confidence Interval obtained using Triangular Distribution

System Cost vs. WMD Pd & Delay Cost







Honor System (Alt 2) Inspects 3 times as many ships as Alt 1