A Simulation Model For Setting Terms For Performance Based Contracts

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Presentation Overview

- ***Heavyweight Torpedo (HWT) Supply Support Overview***
- ***Torpedo Support History*** *~ Long Life Cycle Requirements and Evolving Support Requirements Complicated by End Item Complexities*
- ***Supply Support Concerns***
  - *Historical Background*
  - *Pay Me Now or Pay Me Later*
    - ✓ *Standard Approach Vs Performance Based Logistics (PBL)*
  - *Comparison of Contract Approaches*
  - *Torpedo Acquisition Focus / Critical Factors / Availability*
- ***Torpedo Related Inventory Metrics***
- ***Types of Metrics Important to the Torpedo Enterprise***
  - *Optimizing the Inventory*
  - *Simulation Based Models for Assessing PBL Operations*
- ***Conclusions***

Concept Being Evaluated as Supportability Strategy for MK48 Torpedo

HWT Supply Support Overview

NAVAL Supply Chain ~ NAVSUP

Navy Inventory Control Point ~ Mechanicsburg PA

Program Support Inventory Control Point

- ✓ *Depot Level Repairables (Unique Torpedo Items)*
- ✓ *Initiates Provisioning Process*
  - ➢ *Assigns National Stock No.*
  - ➢ *Updates COSAL*
  - ➢ *Maintains Inventory*

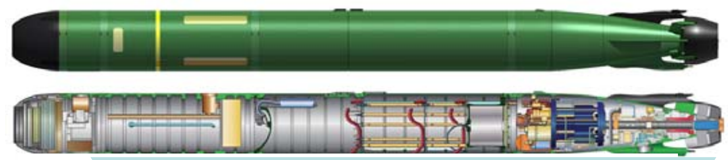
Defense Logistics Agency ~ DLA

- ✓ *Consumable Items*

In-Service Engineering Agent

Technical Data Package ~

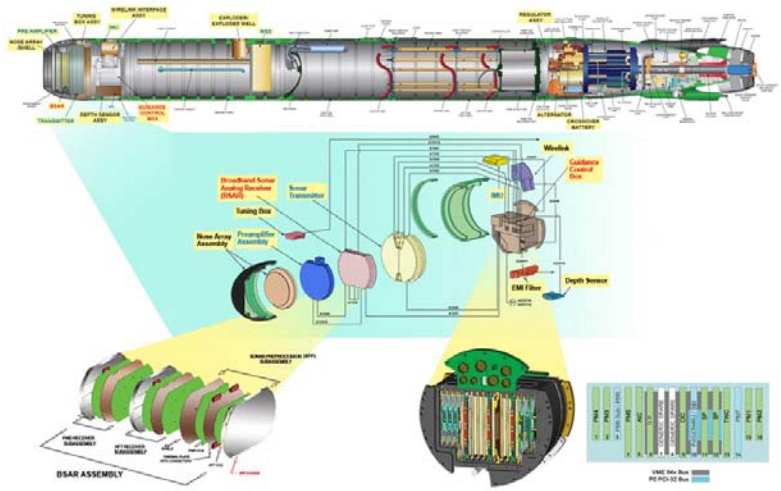
- ✓ *Unique Items*



"Classic" Approach to Spares Support

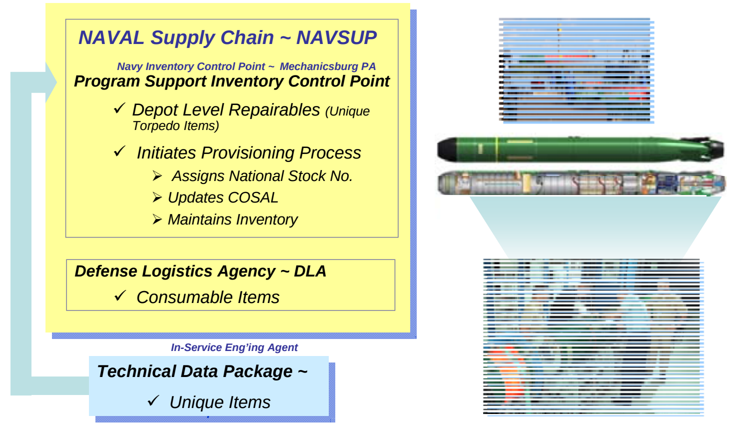
Torpedo Support History

- ***Early Years MK48 Mod 1 - 4*** *(1972-1986) AUR Sole Source*
  - ✓ *Full Technical Data Package (TDP) for Spares*
  - ✓ *Build to Print ~ Navy Supply System Support*
  - ✓ *Low Risk Approach ~ Spares were Concurrent with Production Contracts*
- ***Mid Term Years MK48 Mod 5 ADCAP (1986-1992) AUR Dual Source Competition***
  - ✓ *Full Technical Data Package for Spares*
  - ✓ *Build to Print ~ Navy Supply System Support*
  - ✓ *Low Risk Approach ~ Spares Concurrent with Split Production Contracts*
- ***Acquisition Reform Phase (1995-Present) Modification Kits Competition***
  - ✓ *Forebody Competition Based on High Level Performance Specifications Vs. Detailed TDP*
  - ✓ *Spares Procurement Transitioned from Risk Avoidance to Risk Management Approach*
  - ✓ *Complex Spares Must be Compatible Within and Across Systems ~ Prefer OEM Sources*
- ***Current / Future Support Candidates***
  - ✓ *Part of Production Contract, Long Term Support CLIN, Transition to NAVSUP*



Supply Support Concerns

- **Supply Support Can Be Impacted by Many Factors**
  - *Interchangeability*
  - *Obsolescence*
  - *Rejected Deliverables*
  - *Diminishing Manufacturing Sources*
  - *Contract Default*



- **Forecasting Future Demands is a Growing Challenge**
  - *Implemented Centralized Logistics Support*
  - *Supported NAVSUP's "Special Program Requirements"*
  - *Supported DLA's "Demand Data Exchange"*
  - *Considered OEM Performance Based Logistic Contract (PBL) Via Request For Proposal*
  - *Proposed Performance-Based Production Contract Line Items*

A Long Term Weapon Systems Sustainment Strategy is Needed

Pay Me Now or Pay Me Later

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- ***Standard Spares Contracting Approach ~ Pay Me Later***
  - ***Contract Release, Services, and Spares are Post Production,***
  - ***Executed on an As Needed Basis,***
  - ***Spares Costs Not Included in Starting Contract Cost ~*** *Will Appear Less.*
  - ***Limited Spares Options After Production ~*** *Can result in Increased Costs*
- ***PBL Contract Approach ~ Pay Me Now***
  - ***Contract, Services, and Spares are Concurrent With Production***
  - ***May Need to Reprogram Out-Year Supportability Funding into Current Contract Year*** *(Transition Year) ~ Perceived as Cost Increase*
  - ***Lowers Technical Risk***

PBL Implemented During Production Can Result In More Reliable Designs

Support Contracts

- ***Recent Papers on Support Contracts Highlight Key Points***
  - *Fowler, A, Misunderstood Superheroes, Internet www.dau.mil/pubscats/PubsCats/atl/fow_jf09.pdf, Accessed on March 28, 2010.*
    - ✓ ***PBL is Not Contracting Out Logistics via Product Support Integrator (PSI)***
    - ✓ ***PSI Only Integrates Product Support ~ DoD Still Controls Logistics***
  - *Multiple Sources*
    - ✓ ***Significant Cost Savings through Buying the Result of a Product Vs Actual Repair Parts, Spares, and Maintenance Activities.***
  - *Kim S., Cohen M.A. and Netessine S. (2007), Performance Contracting in After-Sales Service Supply Chains, MANAGEMENT SCIENCE, Vol. 53, No. 12, pp. 1843-1858*
    - ✓ ***Traditional Support Contracts are Best if Contractor's Services are Observable and Defined***
    - ✓ ***PBL Contract is Best if Contractor's Services are Unobservable and All Parties are Risk Neutral***

If PBL Contract is Utilized, Contract Requirements in the Form of Metrics are Essential

Assessing Performance for PBL

- Operational Availability
- Inventory Turns
- MTTF
- MTTR
- Percent of Perfect Orders
- NMC Rates
- Supplier Lead Time
- Supply Chain Response Time
- Product Reliability
- System Reliability

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Metrics Are Not A Two Way Street

- ***Interaction of Metrics as Independent Variables** (X-Axis)* ***and Dependent Variables*** *(Y-Axis)*

  - *The **"Availability"** Metric is Affected by Many of the Other Metrics and May Serve as a Good Indicator of Contractor's Performance on a PBL Contract.*

		Independent Metrics																			
	Optimal Values	0	0%	100%	100%	100%	100%	100%	0	0	0	0	0	100%	100%	100%	0	0	0	0	0
Optimal Values	Dependent Metrics	Inventory Turns	Weapon System NMC Rates	Perfect Order Fulfillment Rate	Percent of Correct Quantity Deliveries	Percent of Defect-Free Deliveries	Percent of Deliveries with Correct Documentation	Percent of On-Time Deliveries	Supply Chain Response Time	Total Source Lead-Time	Handling Lead Times	Receiving Lead Time	Supplier Lead Time	System Reliability	Product Reliability	Operational Availability	Mean Time To Repair (MTTR)	Mean Time To Failure (MTTF)	Mean Logistics Delay Time (MLDT)	Mean Supply Response Time (MSRT)	Mean Accumulated Down Time (MADT)
0	Inventory Turns	\	x						x	x	x	x	x	x	x		x	x			
0%	Weapon System NMC Rates		\	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x
100%	Perfect Order Fulfillment Rate			\	x	x	x	x	x	x	x	x	x								
100%	% of Correct Quantity Deliveries				\																
100%	% of Defect-Free Deliveries					\															
100%	% Deliveries with Correct Documentation						\														
100%	% of On-Time Deliveries							\	x	x	x	x	x								
0	Supply Chain Response Time								\	x	x	x	x								
0	Total Source Lead-Time									\	x		x								
0	Handling Lead Times										\										
0	Receiving Lead Time											\									
0	Supplier Lead Time												\								
100%	System Reliability													\	x						
100%	Product Reliability														\						
100%	Operational Availability			x	x	x	x	x	x	x	x	x	x	x	x	\	x	x	x	x	x
0	Mean Time To Repair (MTTR)			x	x	x	x	x	x	x	x	x	x				\		x	x	
0	Mean Time To Failure (MTTF)													x	x			\			
0	Mean Logistics Delay Time (MLDT)			x	x	x	x	x	x	x	x	x	x				x		\	x	
0	Mean Supply Response Time (MSRT)			x	x	x	x	x	x	x	x	x	x				x		x	\	
0	Mean Accumulated Down Time (MADT)			x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	\

Optimizing The Inventory

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The Newsvendor Problem is a Single Period Mathematical Model Used To Determine Optimal Inventory Levels When the Demand is Uncertain (Porteus, 91)

- *Assume a decision to procure (**q**) items is made at the start of a period.*
- *Subsequently, the random demand (**D**) is revealed.*
- *Distribution of **D** is assumed to be **F(D)**, with a mean **m**.*
- *An ordering/restocking cost of **C** is charged per unit.*
- *If number of items procured >demand, a per unit disposal cost of C_H is charged /period.*
- *If demand > amount procured, a per unit shortage cost of C_P is assessed / period.*
- *Assume **F(x) = 0** for **x < 0**.*
- *For this scenario, the cost function for one period is:*

$$g(y) = Cy + \int_0^y C_H(y-\zeta)dF(\zeta) + \int_y^\infty C_P(\zeta - y)dF(\zeta)$$

- *The optimal order quantity that minimizes the cost is then computed as:*

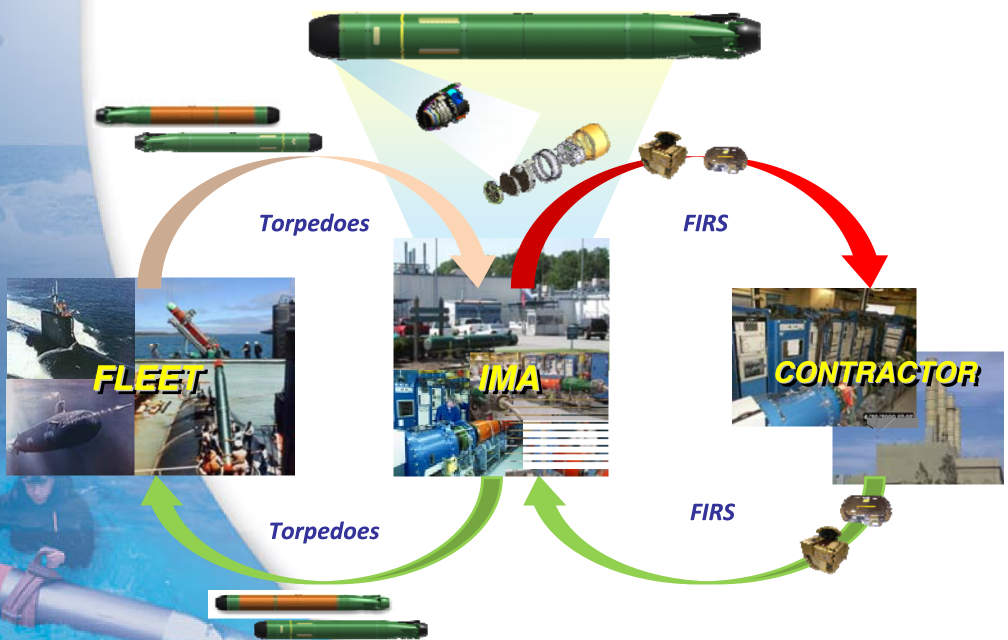
$$F(q^*) = \left(\frac{C_P - C}{C_P + C_H}\right). \qquad \text{or} \qquad q^* = F^{-1}\left(\frac{C_P - C}{C_P + C_H}\right)$$

F^{-1} is the inverse of the distribution function. The quantity (CP – C)/(CP + CH) is the critical fractile and is the optimal probability of not stocking out. [Porteus, 91]

Optimizing The Inventory

- ***Newsvendor Model***
  - ***Applicable to Analysis of Contractor Performance,***
  - ***Can be used for Modeling Operations in PBL Contract with Several Assembly or Subsystem Vendors .***
  - ***Kang & Sanchez, '06, Used Simulation to Show Alternatives Customers Should Specify to Increase Operational Availability / Reduce Readiness Risk.***
    - ✓ ***Transportation/Administrative Delay*** *– Main Determining Factor for Operational Availability.*

- ***PBL Construct For Torpedo Fleet Production Model***



- *Coordinated Shipboard Allowance List (COSAL) is Safety Stock at IMA*
- *Sources of Randomness: Logistical Delay Time, Failure Rates, Minimum Acceptable Operational Availability, Operational Tempo, Seasonal Variation*
- *Cost of Understock is Total IMA Waiting Time*
- *Cost of Overstock is Related to Average Cost of FIR and Cost of Managing / Maintaining Inventory*

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Simulation Based Model For PBL Operations

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- ***Contractor is Responsible for Maintaining FIR Spares at IMA***
- ***Maximum Number of FIRs are Specified in Each IMA COSAL***
- ***Modifications to COSAL to Meet Required Availability can be Negotiated as part of Contract***
- ***If an Incoming Torpedo Needs Replacement FIR, Inventory Status is Determined by Availability Number in System***
- ***Measure of Availability Performance Can be Defined as:***

$$\mathit{Availability} = 1 - \frac{\sum_{i=1}^{T} \text{number of units short}}{\text{total demand in the quarter}}$$

Performance of this Measure is a Function of:

- *Failure Rate,*
- *Stock Level on Shelf, and*
- *Variation in Failure Rates.*

Simulation Based Model For PBL Operations

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- ***Simulation Results for Interaction of Failure Rate, Variation in Failure Rate, and COSAL Value****~ Based on Hypothetical Usage Rate > 500/yr*

Availability

(OPTEMPO = above 500 per year, Logistic Delay = 1 week)

FIR Failure Rate	Failure Rate Variation											
	25%			50%			75%			100%		
↓	Coordinated Shipboard Allowance Level (COSAL)											
	1	2	3	1	2	3	1	2	3	1	2	3
0.05	96.1%	100.0%	100.0%	96.1%	100.0%	100.0%	87.9%	100.0%	100.0%	76.5%	100.0%	100.0%
0.06	89.7%	100.0%	100.0%	83.9%	100.0%	100.0%	74.3%	100.0%	100.0%	65.8%	100.0%	100.0%
0.07	73.2%	100.0%	100.0%	67.5%	100.0%	100.0%	63.4%	97.8%	100.0%	57.1%	95.7%	100.0%
0.08	63.4%	100.0%	100.0%	59.1%	97.9%	100.0%	54.2%	96.0%	100.0%	48.1%	88.3%	100.0%
0.09	56.5%	100.0%	100.0%	51.5%	97.0%	100.0%	46.4%	94.4%	100.0%	43.7%	85.0%	99.2%
0.1	50.0%	100.0%	100.0%	47.3%	93.6%	100.0%	42.6%	84.4%	100.0%	39.1%	75.4%	98.5%
0.11	47.7%	93.6%	100.0%	41.3%	85.2%	100.0%	40.3%	74.5%	99.3%	35.4%	71.7%	94.6%
0.12	40.9%	86.7%	100.0%	38.5%	77.6%	100.0%	35.4%	70.7%	97.3%	32.7%	65.8%	92.0%
0.13	38.8%	78.8%	100.0%	35.9%	69.8%	98.6%	32.7%	64.6%	93.7%	30.6%	61.5%	88.9%
0.14	36.9%	73.8%	100.0%	34.2%	65.0%	95.5%	30.4%	62.3%	88.8%	27.7%	55.6%	82.0%
0.15	33.5%	70.3%	98.7%	30.4%	62.7%	90.1%	28.4%	58.1%	84.2%	26.1%	52.0%	78.3%

Table Entries are the Average (>1000 Runs) of the Availability Metric for a Given Failure Rate and a Random Variation (uniformly distributed) for Different COSAL Levels

Monte Carlo Simulation Inputs/Outputs

- ***INPUTS***
  - ***2000 variations of a FIR-like Product***
  - ***Exponentially Distributed Failures over 1000 Periods***
  - ***Variations created using randomly generated:***
    - ✓ *Failure Rate,*
    - ✓ *OPTEMPO,*
    - ✓ *Logistical Delay Time,*
    - ✓ *Minimum Operational Availability,*
    - ✓ *Storage Cost, and*
    - ✓ *Shortage Cost.*

MONTE – CARLO SIMULATION

- ***OUTPUTS***
  - ***Optimal COSAL based on Random Inputs***
  - ***Correlation Graphs between COSAL and:***
    - ✓ *Failure Rates,*
    - ✓ *OPTEMPO,*
    - ✓ *Logistical Delay Time,*
    - ✓ *Minimum Operational Availability,*
    - ✓ *Storage Cost,*
    - ✓ *Shortage Cost.*

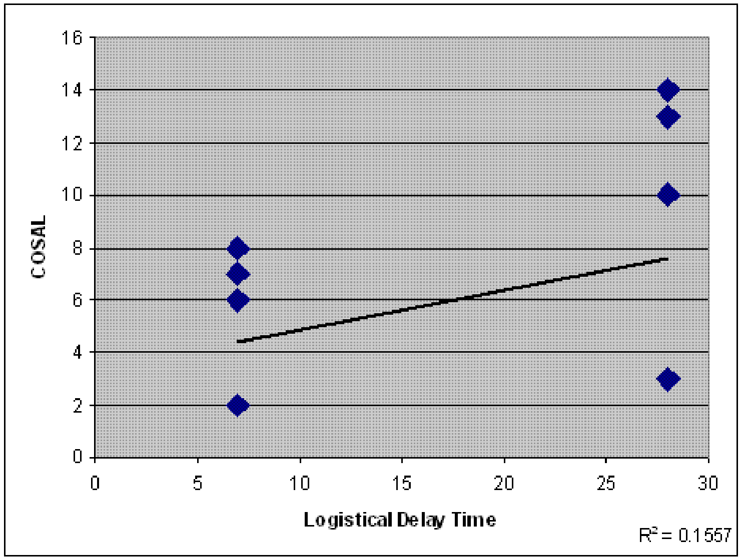
Model Parameters and Correlations

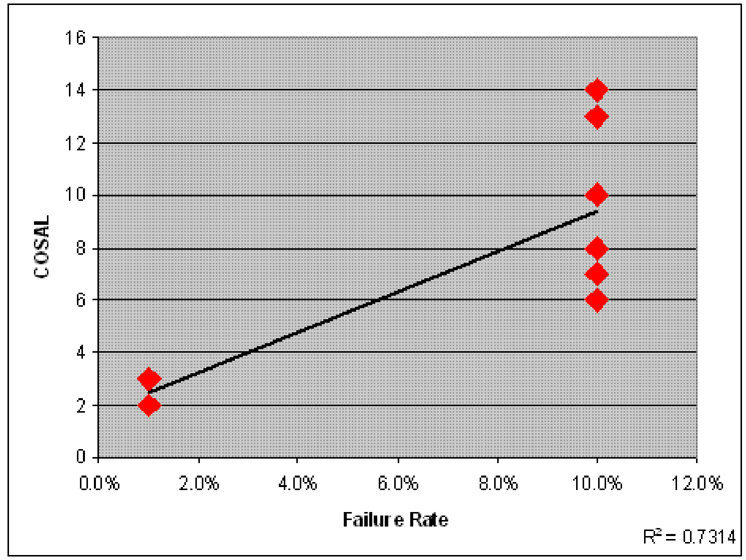
- ***Monte Carlo Simulation***
  - ***Optimal COSAL calculated for High and Low variations of the Failure Rate, Minimum Operational Availability, OPTEMPO, Logistical Delay Time, Shortage Cost, and Storage Cost.***

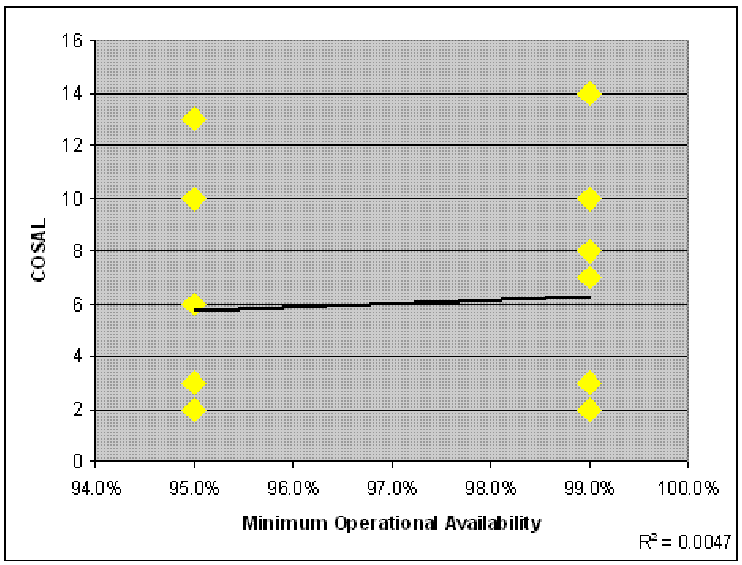
✓ ***Failure Rate:***	*High = 10%*	*Low = 1%*
✓ ***Logistical DT:***	*High = 28 days*	*Low = 7 days*
✓ ***Minimum Ao:***	*High = 99%*	*Low = 95%*
✓ ***OPTEMPO:***	*High = 1000*	*Low = 500*
✓ ***Shortage Cost:***	*High = $1000*	*Low = $500*
✓ ***Storage Cost:***	*High = $100*	*Low = $50*

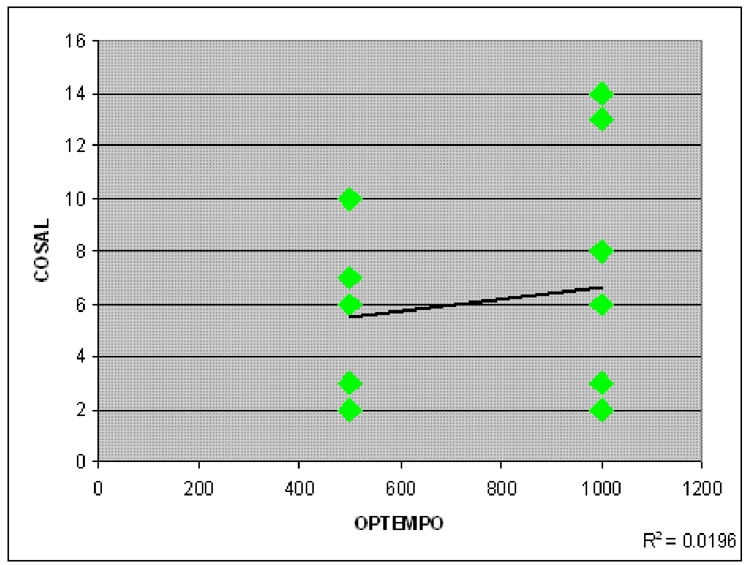
  - ***Generated Correlation Graphs between COSAL and Failure Rate, Minimum Operational Availability, OPTEMPO, Logistical Delay Time, Shortage Cost, and Storage Cost.***

Correlation Graphs









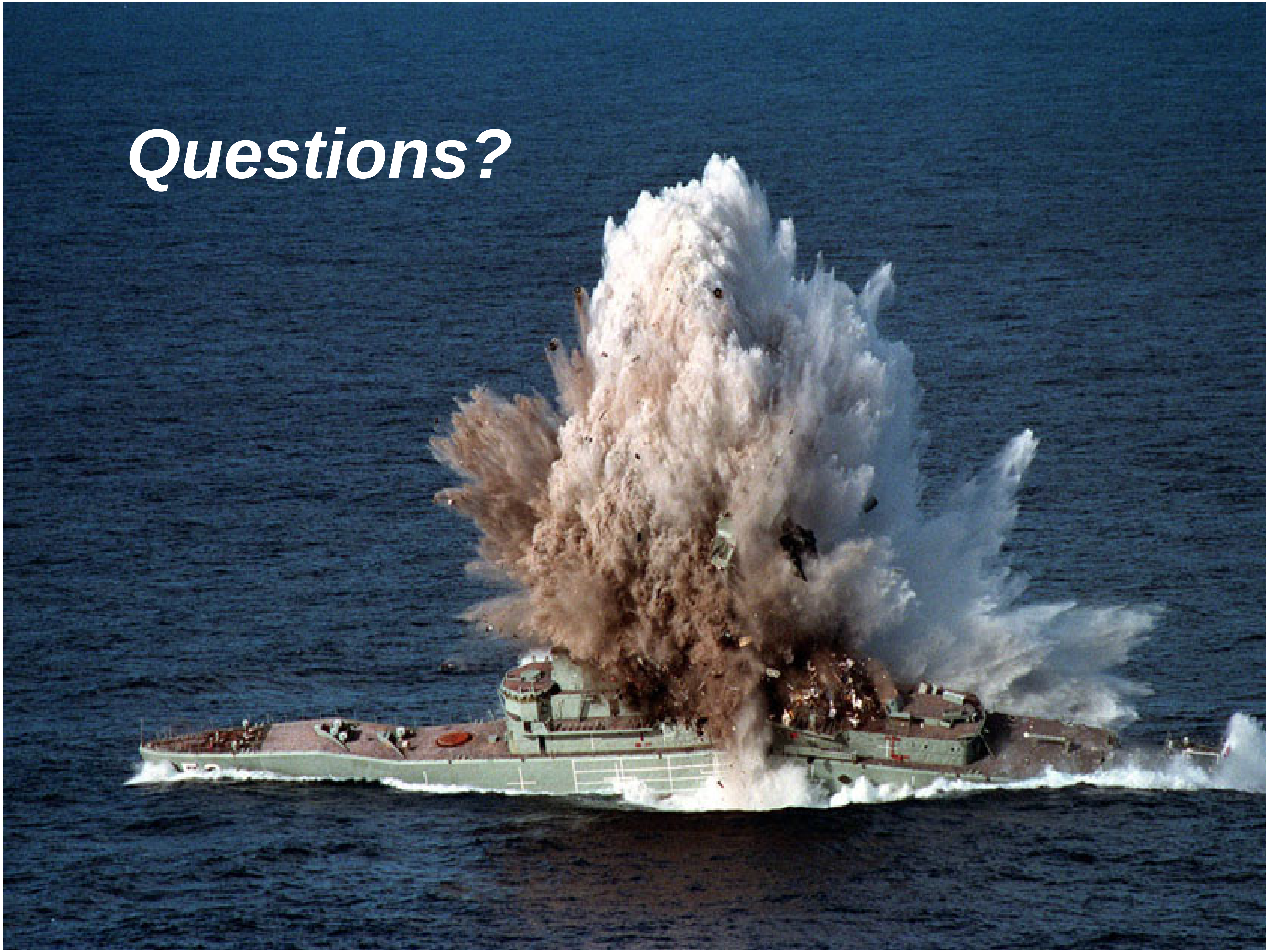
Simulation Based Model For PBL Operations

- ***Simulation Observations***
  - ***Shows that Failure Rates Correlate with COSAL; As Failure Rate Drops, Support COSAL Required Decreases***
  - ***Simulation is More Complex Than Newsvendor Model***
    - ✓ ***Addresses Typical Variations in Exercise Rate***
    - ✓ ***Addresses Changes in Logistic Delays***
  - ***Simulation Can be Used When Negotiating with Contractors Prior to Award*** *~ Assess Impact of Contractor's Estimated Failure Rate*
  - ***An Extension of Simulation Allows an Optimization of the COSAL Required to Achieve a Given Service Level***

Advantage of Simulation / Optimization is that it Dispenses With Assumptions of independence of Failure Rates that are Often Necessary for Analytical Solutions and Distributional Assumptions

Conclusions

- ***PBL Type Contract is Candidate Support Approach for the Torpedo Enterprise***
  - ***PBL Contract is Best if Contractor's Services are Unobservable and All Parties are Risk Neutral ~ (Kim et al, '07)***
  - ***Potential for Significant Cost Savings ~*** *Buy A Result (Availability) Vs Actual Repair Parts, Spares, and Maintenance Activities.*
  - ***Contract Requirements in the Form of Metrics are Essential***
    - ✓ *Within the Torpedo Enterprise, Assembly / Subassembly Availability is a Key Metric*
  - ***Simulation Can be Used When Negotiating with Contractors Prior to Award*** *~ Assess Impact of Contractor's Estimated Failure Rate and Optimize COSAL*


Questions?

BACKUP SLIDES