Improving Ship Maintenance with Collaborative Product Life Cycle Management and 3D Terrestrial Laser Scanning Tools:

Reducing Costs and Increasing Productivity

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Research Context

- Part of a project to test the application of Modern Portfolio Theory to naval acquisition
- This is a progress report, not final results
- Application of integrated Knowledge Value Added (KVA), System Dynamics (SD), and Integrated Risk Management (IRM)
- Based on previous demonstration of integrated use of KVA and SD (NPS-GSBPP-10-015)

The Fleet Maintenance and Improvement Analysis Challenge

- Getting the “Biggest Bang for the Buck” (Benefit/Cost Analysis) requires including changes in benefits as well as changes in costs
- A purely-cost focus can cut more efficient programs and efforts that cost more
- Analysis of cost-saving programs must include program benefits in program analysis to identify the best programs to invest in.

Example: The Shipmain Process of Ship Improvement

- Industry reduces costs through repeating non-redundant processes to capture learning curve effects.
- Navy has been unable to capture similar learning curve based cost savings in shipyards
- Shipmain revised (2006) ship improvement process to generate timely, effective, and affordable planning, budgeting, engineering, and installation of shipboard improvements

The Shipmain Process

- Develop and adopt a common planning process for maintenance and alterations – eliminate process redundancies
- Apply best business practices to reduce costs based on learning curve. The original Shipmain plan included:
  - **3D Terrestrial Laser Scanning Technology** (3D TLS)
  - **Collaborative Product Lifecycle Management** (collab-PLM) process and tools

3D Terrestrial Laser Scanning

- Laser scans space from highly articulated mount
- Software processes points into 3D image of the space (within 3/16”) ready for CADD, etc.
- Can be combined with 360^{o} camera
- Currently used in automotive, offshore construction and repair, civil and transportation, building construction, fossil fuel and nuclear power plants

Collaborative Product Lifecycle Management

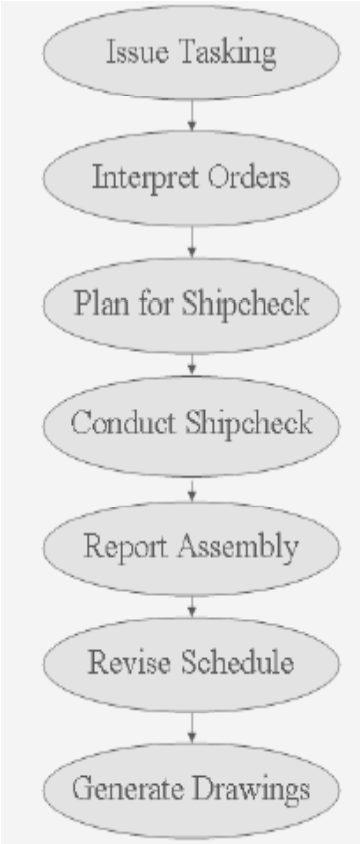
- To “integrate people, processes, and information”
- Electronically integrates 3D TLS for participant collaboration across physical distances
- Common database of images and related data for improved access
- Common platform for program change management

Impacts of 3D TLS and Collaborative PLM on Shipmain

- **Operations**
  - Faster ship condition data collection
  - Shorter ship visits
  - Faster translation of ship conditions to information for design
  - Faster conflict identification
  - Automate drawing development
- **Result:** Cycle time reduction (40-60% in other industries)
- Initial purchase and installation cost ($1.6m)

Modeling Shipmain Planning Processes

- Focus on ship improvement planning processes
- SD expansion of existing steady state model (NPS-AM-06-003) to better reflect actual conditions…
- Seven mostly sequential core processes →
- 28 unique subprocesses
  - Simulate operational benefits of operations (common units of outputs)
  - Simulate operating costs
  - Calculate unit cost ($/common unit)



Improved Modeling of Benefits and Costs

Benefits

- *More realistic description of possible benefits with different number of yards using* 3D-TLS + collabPLM
- Faster processes create increased ships processed if 3D-TLS + collabPLM are adopted due to the *reduced cycle time*
- *Lifespan* of use of 3D-TLS + collabPLM before adoption of a new technology – longer lifespan increases benefits

Costs

- *Initial costs* to purchase and install collab. PLM software and license users
- *Costs to install* 3D-TLS at the shipyards
- Reduced operations cost/ship due to faster processes

Simulation Cases and Results

$$\text{Savings} = (\text{UnitCost}_{\text{as-is}} - \text{UnitCost}_{\text{to-be}}) * \text{Ships Improved}_{\text{to-be}}$$

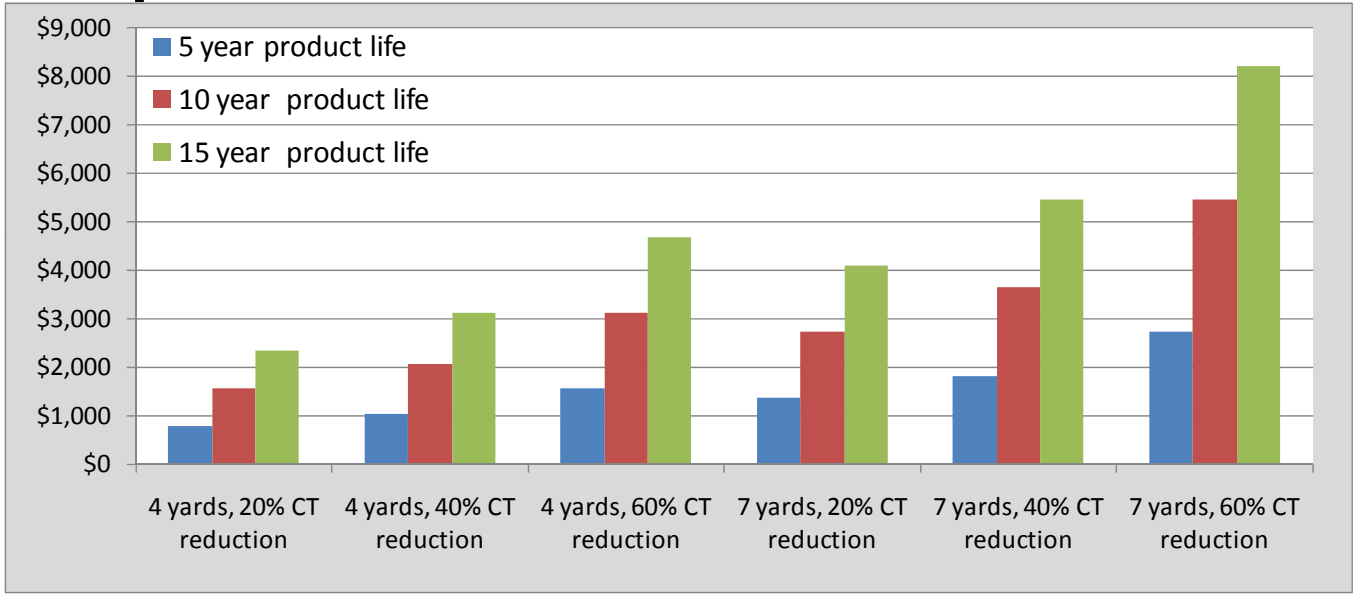
Simulated SHIPMAIN Cost Savings due to Adoption of 3D TLS and Collaborative PLM

Shipmain Cost Savings (* $1,000,000)		Scale of Adoption and Cycle Time Reduction					
		4 yards. 20% CT reduction	4 yards. 40% CT reduction	4 yards. 60% CT reduction	7 yards. 20% CT reduction	7 yards. 40% CT reduction	7 yards. 60% CT reduction
Product Life	5 years	$776	$1,038	$1,559	$1,362	$1,819	$2,731
	10 years	$1,555	$2,076	$3,121	$2,726	$3,639	$5,465
	15 years	$2,333	$3,116	$4,680	$4,091	$5,461	$8,199

Forecasted savings = $776m - $8,199m

Simulation Results

Simulated SHIPMAIN Cost Savings ($million) due to Adoption of 3D TLS and Collaborative PLM



Cost savings increase with the number of yards adopting collaborative PLM and 3D TLS, product life span, and the size of the reduction in cycle time.

Potential Model Improvements for Planning Adoption of 3D-TLS + collabPLM

- **Ramp-up of adoption** (expect lower early savings and more with longer usage)
- **Variance in process rates** over time (unclear impact)
- **Share costs with ship design and construction** processes (expect large savings increase)

Integrated Risk Management

1 List of projects and strategies

RISK IDENTIFICATION

SME

A
B
C
D
E

Start with a list of projects or strategies to be evaluated… these projects have already been through qualitative screening

2 Base case projections for each project

RISK PREDICTION

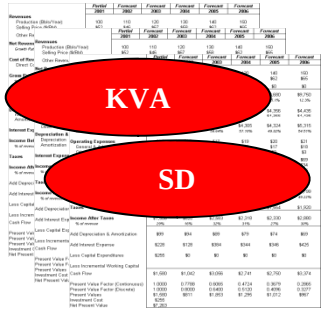
FORECASTING

Time Series Forecasting

…with the assistance of time-series forecasting, future outcomes can be predicted...

3 Develop static financial models

RISK MODELING



KVA

SD

Traditional analysis stops here!

…the user generates a traditional series of static base case financial (discounted cash flow) models for each project…

4 Dynamic Monte Carlo simulation

RISK ANALYSIS

RISK SIMULATION

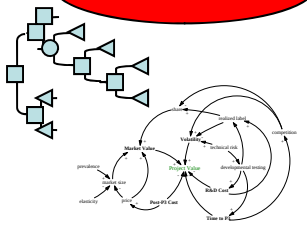
Lognormal

…Monte Carlo simulation is added to the analysis and the financial model outputs become inputs into the real options analysis…

5 Framing Real Options

RISK MITIGATION

COA-AOA



…the relevant projects are chosen for real options analysis and the project or portfolio real options are framed…

6 Options analytics, simulation optimization

RISK HEDGING

Simulation

Lattice

REAL OPTIONS

…real options analytics are calculated through binomial lattices and closed-form partial-differential models with simulation…

7 Portfolio optimization and asset allocation

RISK DIVERSIFICATION

OPTIMIZATION

Effects of Waiting
Defray cost
Other opportunities
Loss revenues
Loss cost reduction
Loss of market leadership

Decision

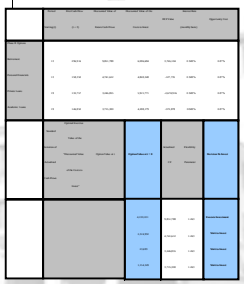
Effects of Going
Revenue enhancement
Cost reduction
Strategic options value
Strategic competitiveness
High cost outlay

…stochastic optimization is the next optional step if multiple projects exist that require efficient asset allocation given some budgetary constraints… useful for strategic portfolio management…

8 Reports presentation and update analysis

RISK MANAGEMENT

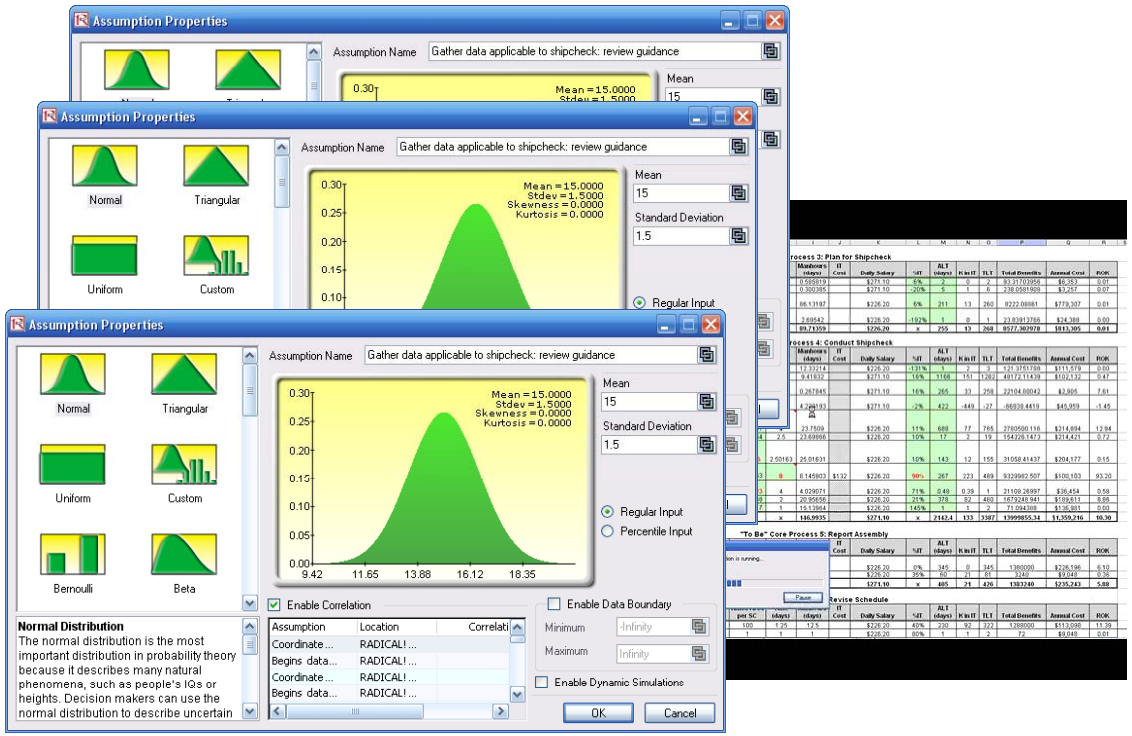
UPDATES



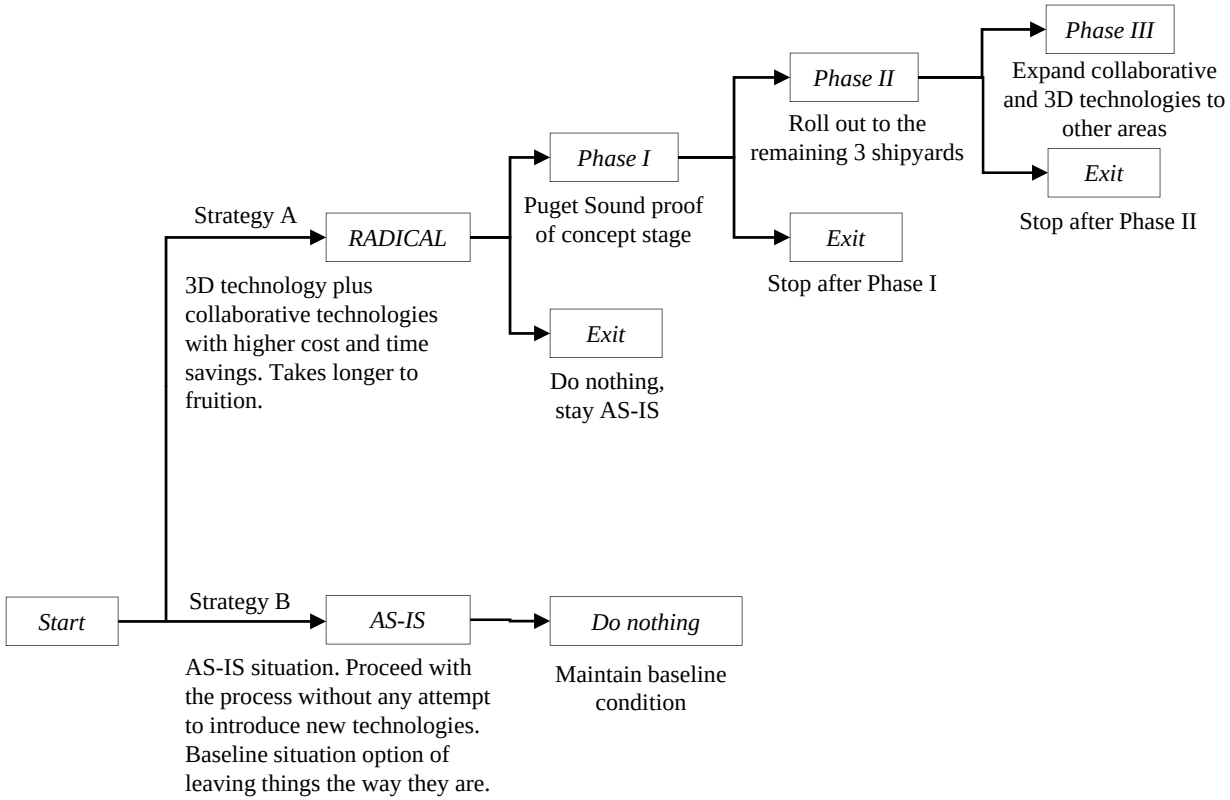
…create reports, make decisions, and do it all again iteratively over time…

Next Steps:

Monte Carlo Risk Simulation is run (10,000-1,000,000 trials)



Next Steps:
Framing the Strategic Options (COA/AOA)



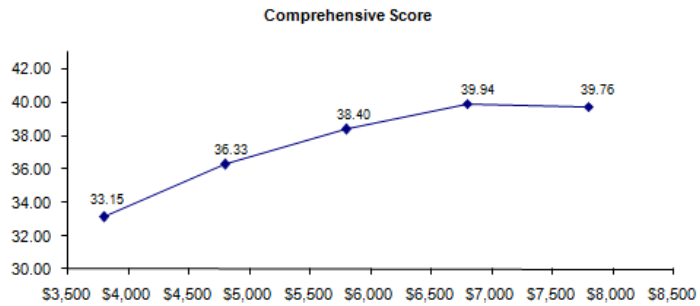
Modern Portfolio Theory Applications

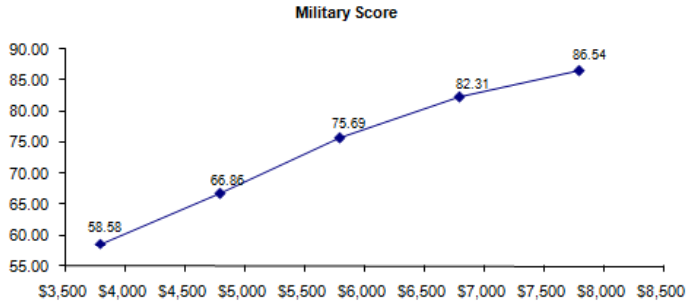
- Theory evolved from Markowitz to Sharpe
- OPTIMAL portfolio diversification, portfolio allocation, project selection
- Objective is to maximize returns or benefits with the least amount of cost and schedule risk, subject to some budget, time, or cost constraints
- SHIPMAIN: upstream and downstream applications…

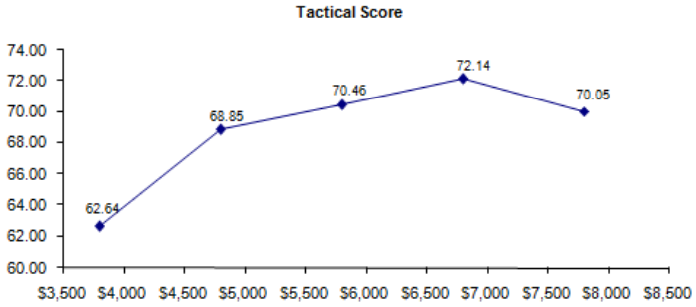
Next Steps:

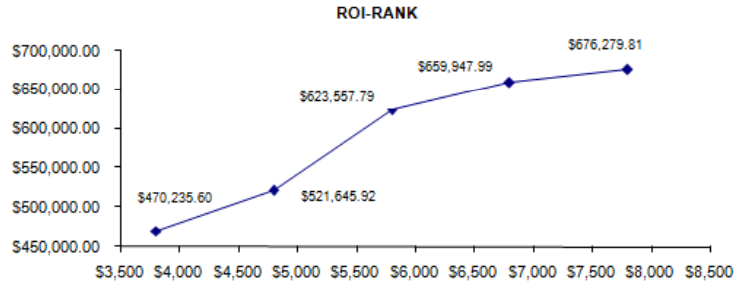
Investment Efficient Frontiers analysis provides for a variety of budget scenarios when considering portfolios of options

Budget	Comprehensive Score	Tactical Score	Military Score	Allowed Projects	ROI-RANK Objective
$3,800.00	33.15	62.64	58.58	10	$470,235.60
$4,800.00	36.33	68.85	66.86	11	$521,645.92
$5,800.00	38.40	70.46	75.69	12	$623,557.79
$6,800.00	39.94	72.14	82.31	13	$659,947.99
$7,800.00	39.76	70.05	86.54	14	$676,279.81









Conclusions

- Adopting 3D-Terrestial Laser Scanning and Collaborative Product Lifecycle Management can greatly reduce Shipmain costs
- Additional modeling can facilitate the planning of adoption implementation
- Modern Portfolio Theory may be capable of describing and facilitating the design of collections of navy assets that better balance risk and reward subject to cost and schedule risk minimization

Questions?
Comments?
Discussion?