Acquiring Enterprise Systems as a Portfolio of Real Options

Ronald E. Giachetti, Ph.D.

Professor
Systems Engineering
Naval Postgraduate School
Monterey, CA
regiache@nps.edu

May 18, 2012

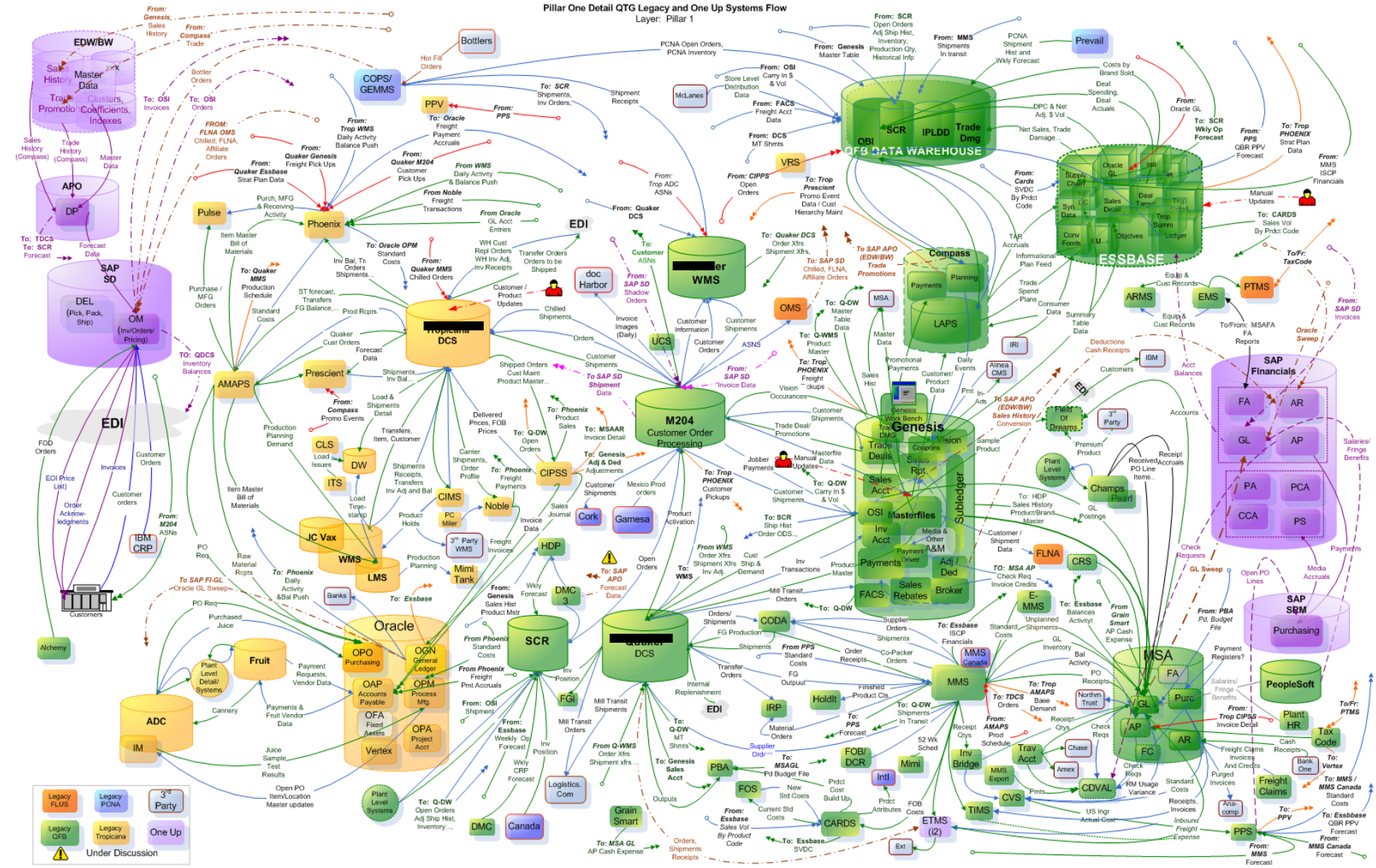
Motivation

- Enterprise architecture (EA) is designed and acquired in an evolutionary manner over a long period of time
  - Complex systems
  - High uncertainty and project risk
  - Changing needs, technology, resources (budgets), and priorities

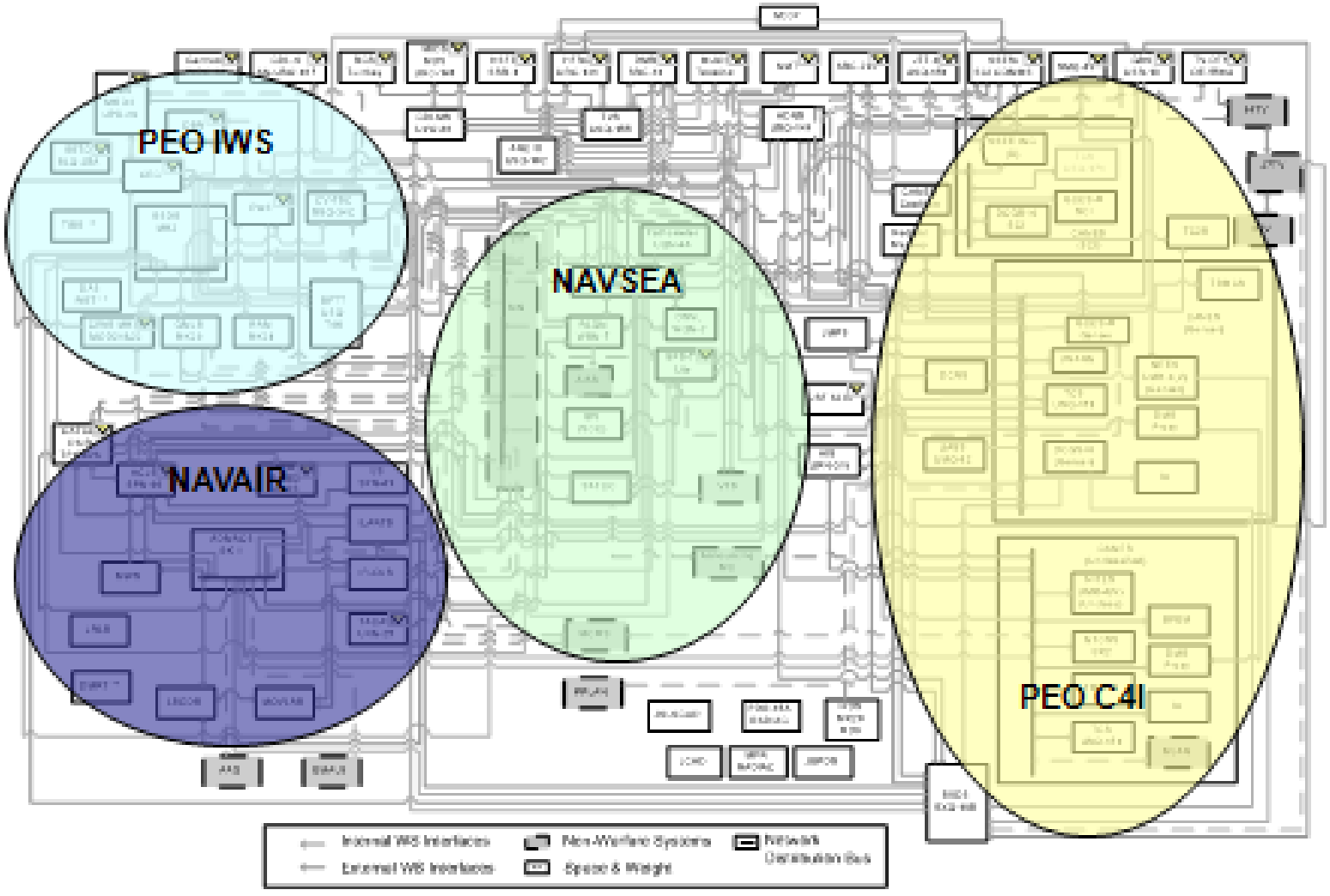
- Researching Two Approaches:
  1. analyze architectures before constructing them -- reduce uncertainty
  2. Structure system architecture to support flexible acquisition coupled with decision tools ***to react*** to new information as project unfolds

Enterprise Systems in a Large Beverage Co.

Do you think it was architected like this?



Today's Shipboard Environment
(Direct interfaces, unique solutions, weak cross-domain integration)

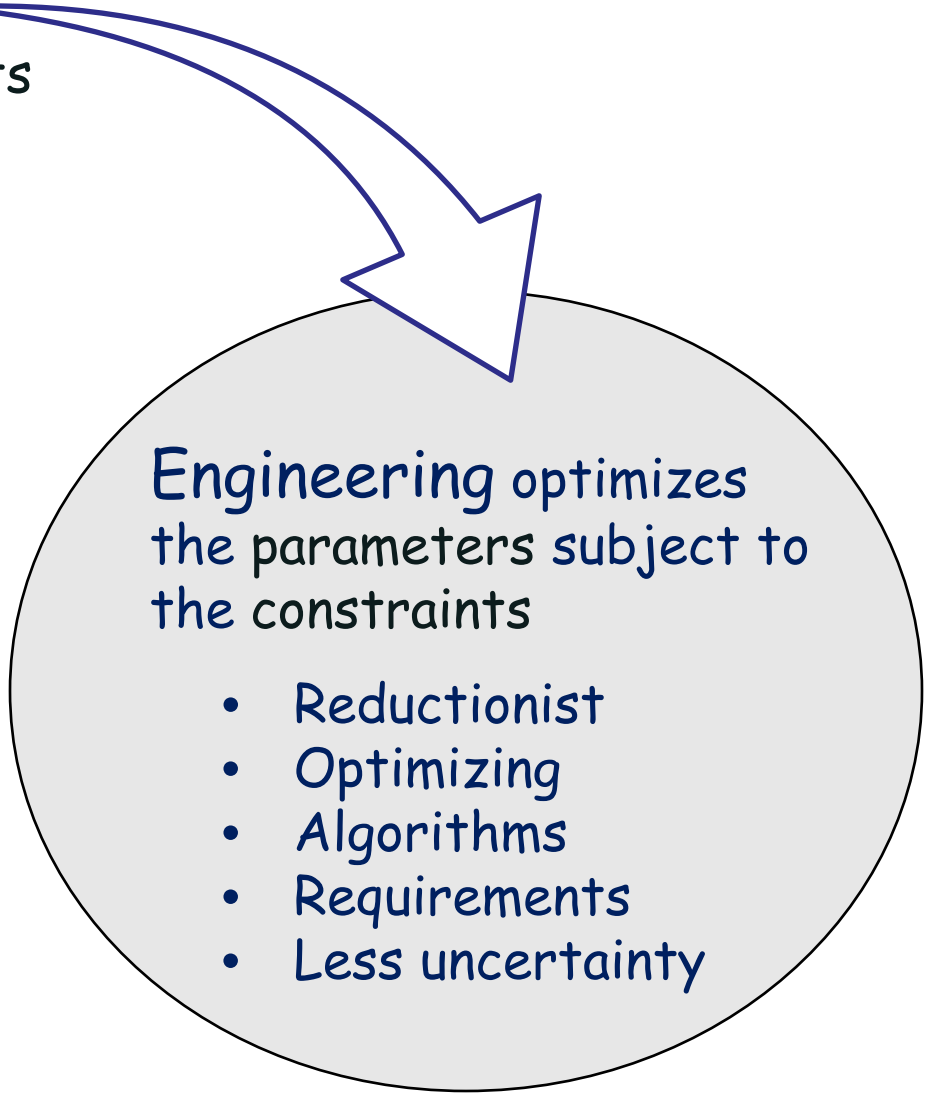


Source: "Surface Navy Combat Systems Engineering Strategy" Briefing to NPS. Kathy Emery, Chief Architect, PEO Integrated Warfare Systems, 4 March 2010

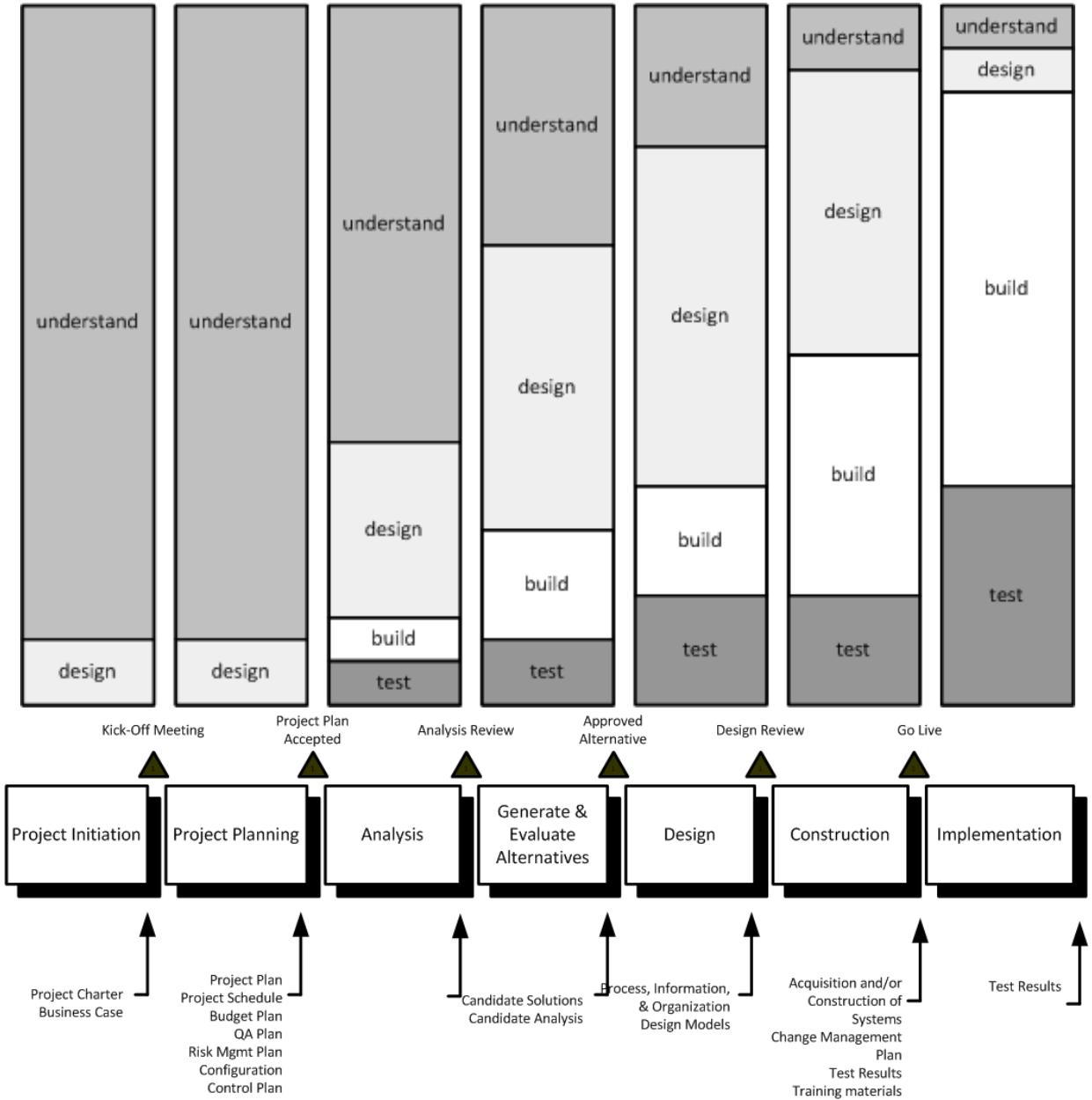
Architecture & Engineering

Architecture defines the parameters and overall constraints

- Holistic
- Satisficing
- Heuristic
- Ambiguous 'fuzzy' needs
- High uncertainty

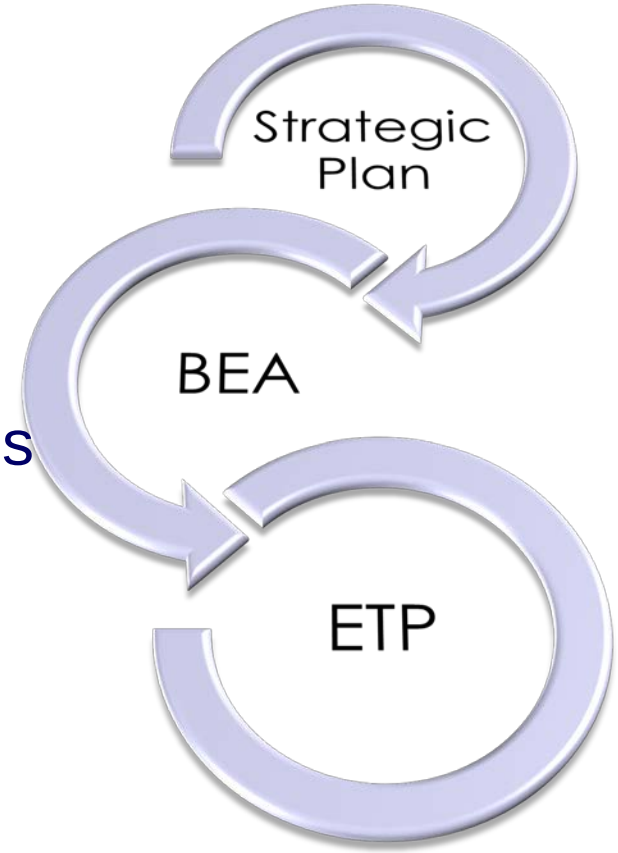


Enterprise Systems Engineering Process

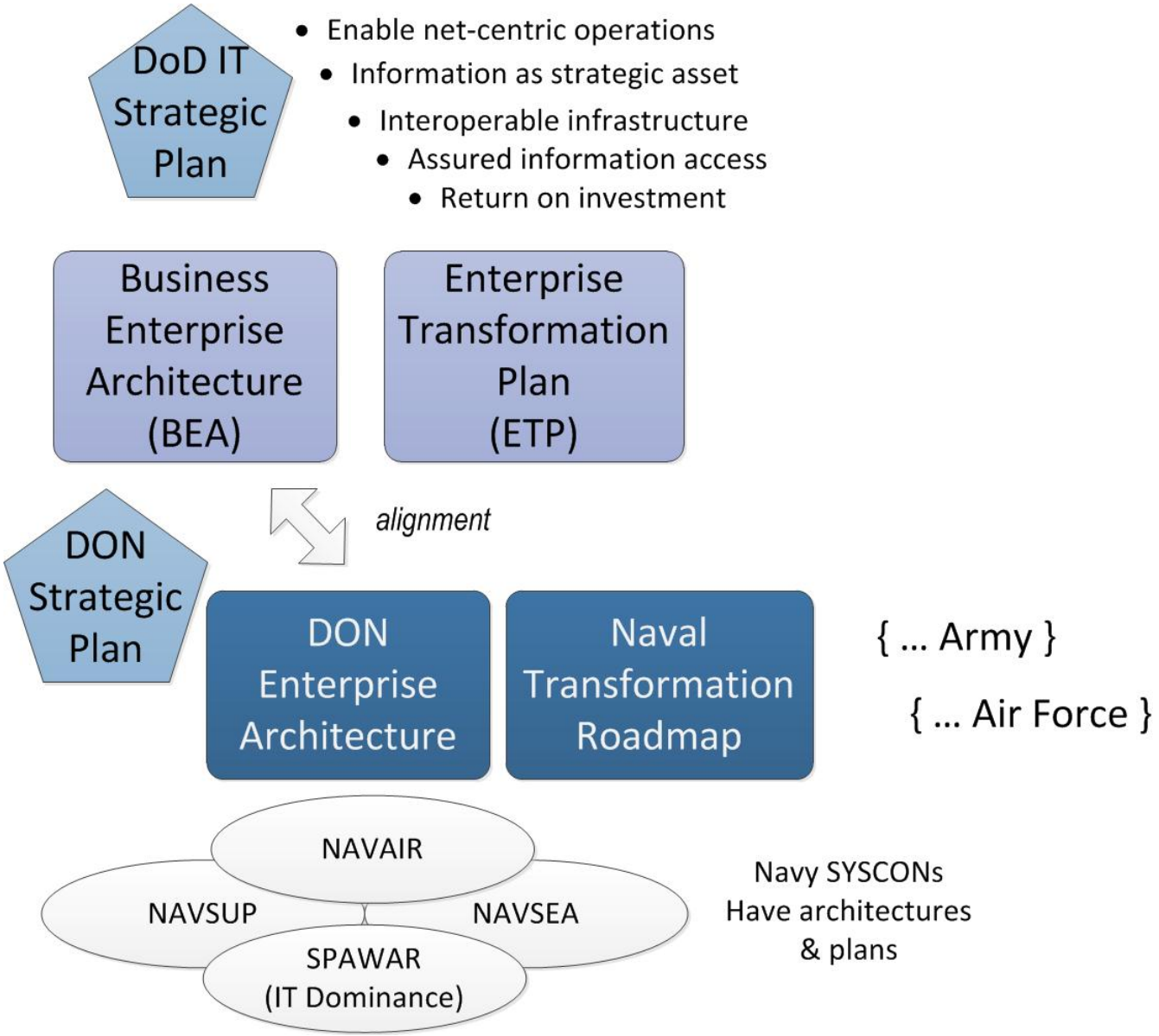


EA Design Evolution

- EA does not start with a **blank sheet of paper**
  - it is the transformation of existing architecture (As-Is) to a target architecture (To-Be)
  - In large organizations, it is hierarchical, involving many levels of planning and system design



Enterprise Architecture



Tech Authority Approach for Controlling Navy IT

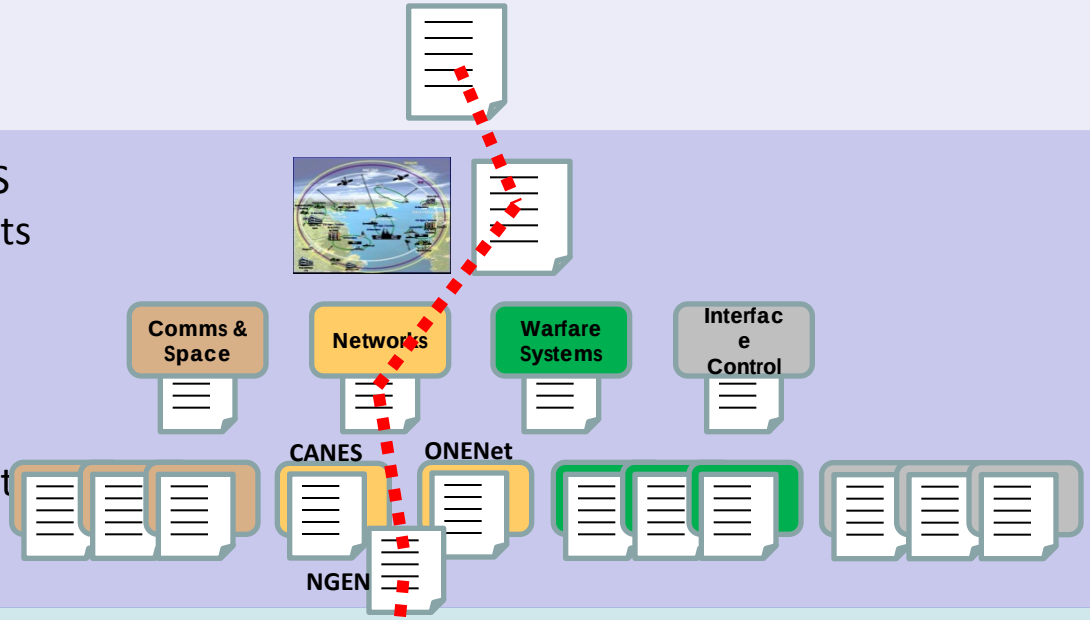
Information Dominance Mission Needs Document

N2N6

Information Dominance SoS Architecture & Requirements

Portfolio Requirements
Portfolio I/F Control Doc

PEO/Platforms Requirement
PEO/Platform Control Docs



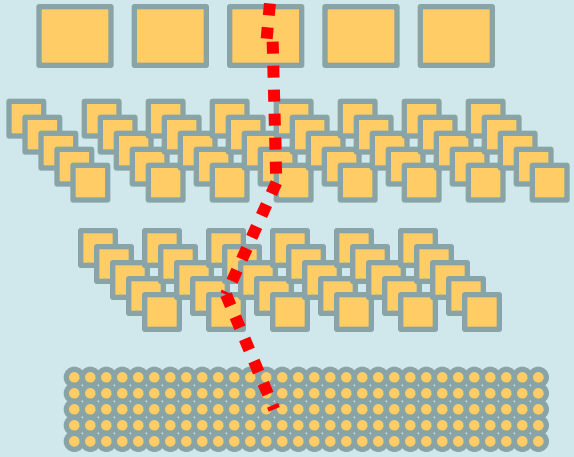
SPAWAR CHENG

NGEN Mission Segments (5)

NGEN Services (38)

NGEN Systems (24)

NGEN CI ("box" design)



PEO/PMW

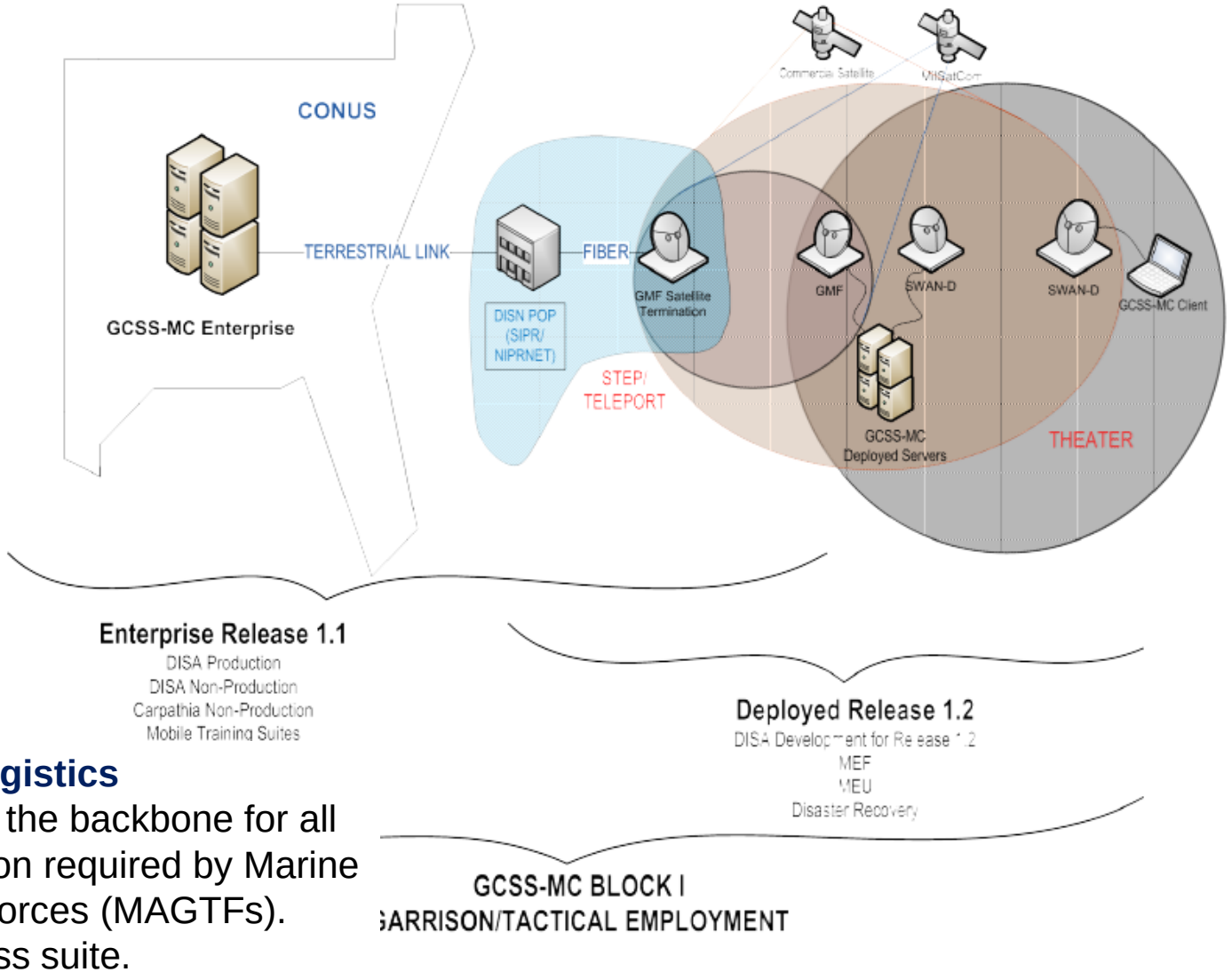
Assured traceability from mission needs to implementation

Flexible Realization of EA

- Define projects as portfolio of real options
  - Modularization of EA into projects – breadth and time dimensions
  - Active management of systems engineering project via real options

- Incorporate alternatives into planning process
- Defer some decisions until uncertainty can be resolved

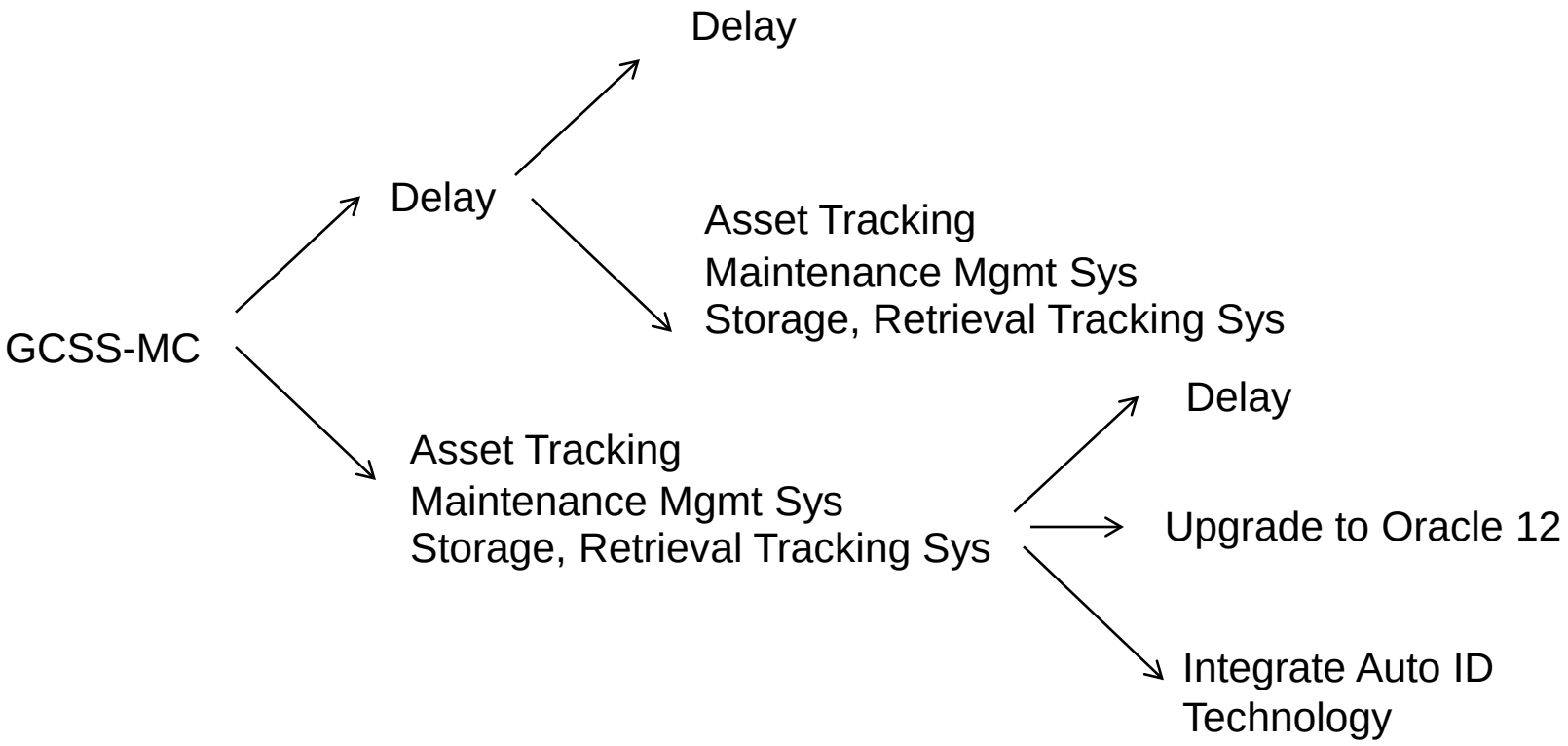
Phased modular deployment



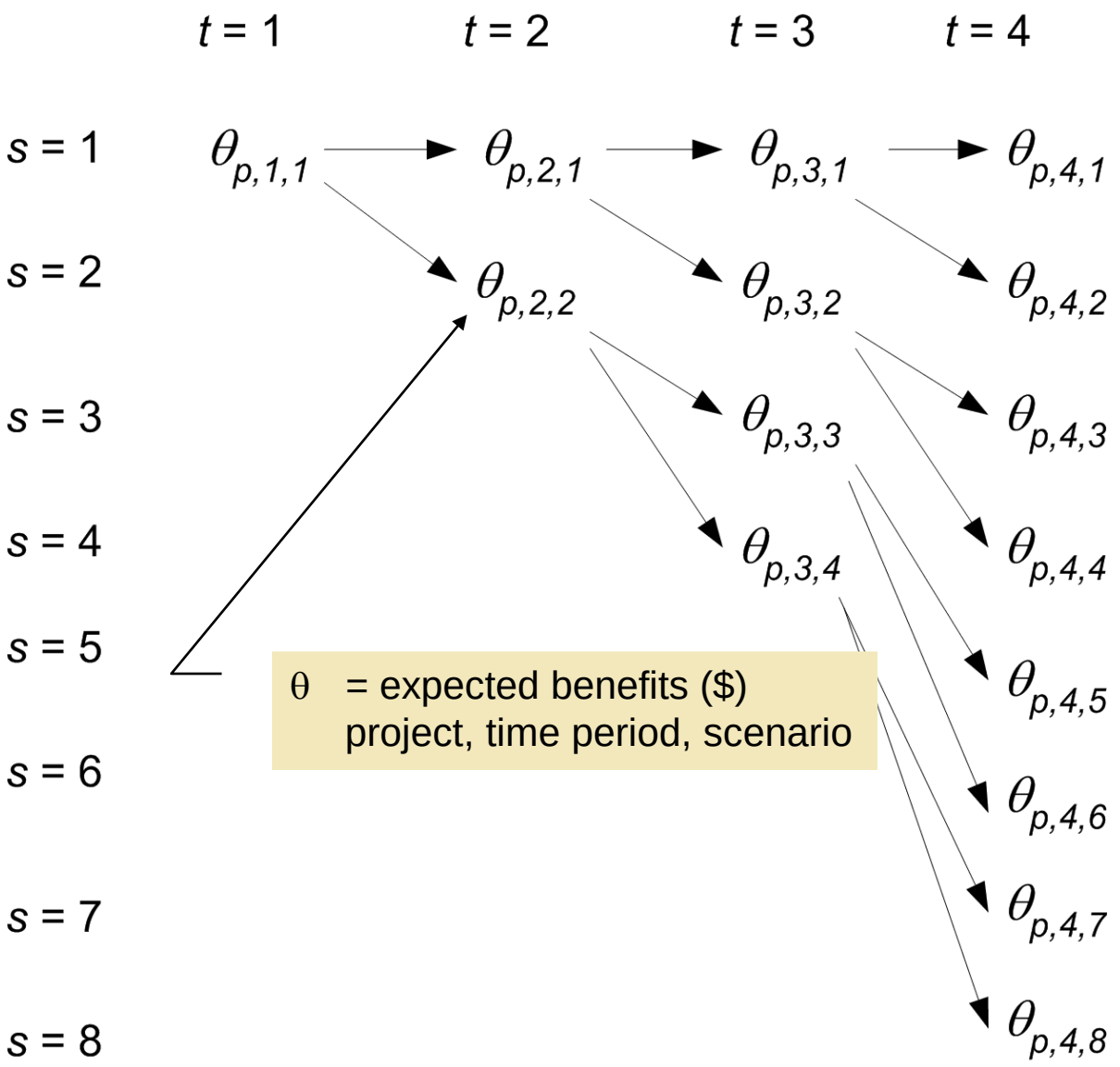
Marine Corps Logistics Modernization is the backbone for all logistics information required by Marine Air ground Task Forces (MAGTFs). Oracle 11i business suite.

Converting Project to RO

Global Combat Support System Marine Corps (GCSS-MC) – Technology enabler for Logistics Modernization strategy; An Oracle 11i e-business suite to replace multiple legacy systems.



Binomial Tree

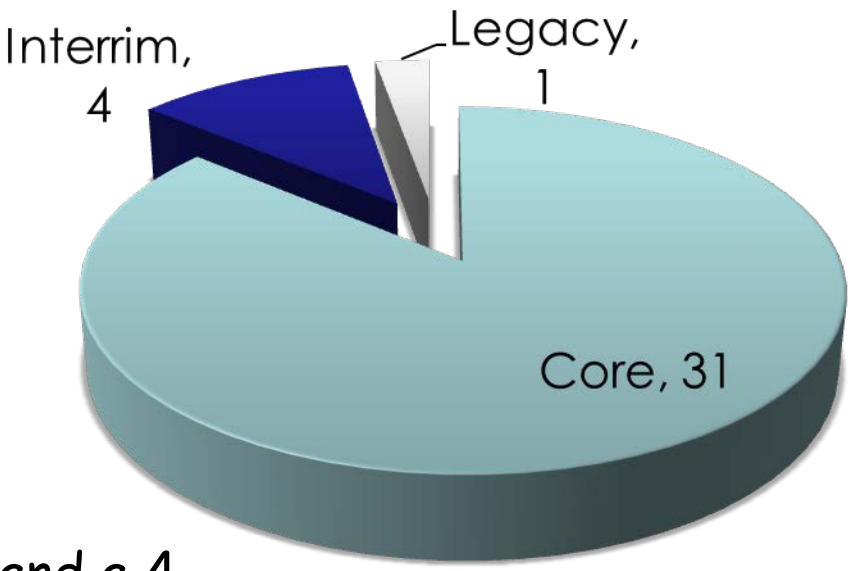


A single project *p* whose associated random variable has two possible outcomes: Improvement (UP) or Worse (DOWN)

Requires 15 calculations for option value by **time period** and **scenario**

Problem Tractability

In 2011, Navy has 36 active enterprise system projects



In a portfolio of 36 projects and a 4-year planning horizon, there are more than 68 billion possible states after the first year

Provides a capability(ies)

Model

θ_{pt}

Net present value of costs and benefits for project *p* in time period *t*

a_i

i denotes state of project (e.g., *i* = 1 for delay/abandon; *i*=2 for pilot; *i*=3 for expand)

No scenario – Monte Carlo

Decision Variable:

Denotes the decision for project *p* and time period *t*, whether to switch from state *a* to state *a'*

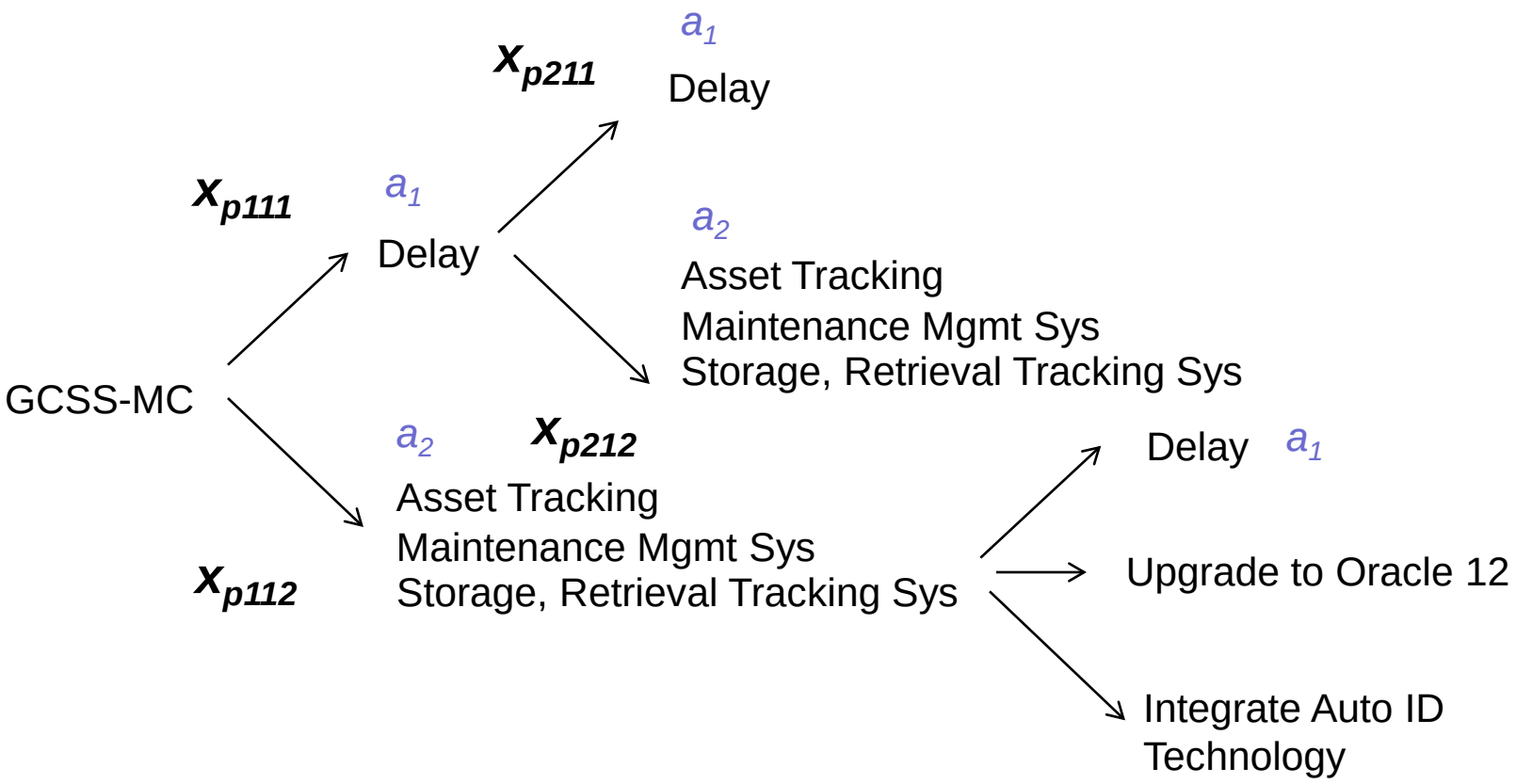
$x_{ptaa'}$

1 denotes switch from a to a'

0 otherwise

Converting Project to RO

Global Combat Support System Marine Corps (GCSS-MC) – Technology enabler for Logistics Modernization strategy; An Oracle 11i e-business suite to replace multiple legacy systems.



Correlation – Portfolio Effects

In a portfolio of projects, it is likely that some project benefits/costs are correlated

Estimate correlation

Correlation	Value
Correlated	1 (-1)
High	0.75 (-0.75)
Moderate	0.5 (-0.5)
Minor	0.25 (-0.25)
Not	0

	P1	P2	P3	P4	P5
P1	1	0	0.25	-0.25	0.25
P2		1	0.5	-0.25	0.5
P3			1	0.5	0.5
P4				1	0.5
P5					1

Discrete Stochastic Optimization Model

Equations to value the options and enforce the budget constraint

$$\max Z = \sum_{p \in P} \sum_{a' \in A} V_{p,1,1} x_{p,1,1,a'} \quad (1)$$

$$c_{p,t,a} = f_{p,a} + \lambda_{p,a} \theta_{p,t} \ \vee p \in P, t \in T, a \in A \quad (2)$$

$$V_{p,T,a} = \sum_{a' \in A} x_{p,T,a,a'} \left(c_{p,T,a'} - I_{p,T,a,a'} \right) \quad (3)$$
$$\vee p \in P, t = T, a \in A$$

$$V_{p,t,a} = \sum_{a' \in A} x_{p,t,a,a'} \left(c_{p,t,a'} - I_{p,t,a,a'} \right) \quad (4)$$
$$+ \frac{(V_{p,t+1,a'})}{e^{r \Delta t}}$$
$$\vee p \in P, t = 1..T-1, a \in A$$

$$\sum_{a \in A} \sum_{a' \in A} x_{p,t,a,a'} = 1 \ \vee p \in P, t \in T \quad (5)$$

$$x_{p,1,a,a'} = 0 \ \vee p \in P, a \neq 1, a' \in A \quad (6)$$

$$\sum_{a' \in A} x_{p,t,\hat{a},a} = \sum_{a \in A} x_{p,t-1,a,\hat{a}} \ \vee p \in P, t \in [2,T], \hat{a} \in A \quad (7)$$

$$B_{p,1,s,a'} = \beta_1 - \sum_{p \in P, a' \in A} \left(x_{p,1,1,a'} - I_{p,1,1,a'} \right) \quad (8)$$

$$B_t = B_{t-1} + \beta_t - \sum_{p \in P, a, a' \in A} x_{p,t,a,a'} I_{p,t,a,a'} \ \vee t \in [2..T] \quad (9)$$

$$B_t \geq 0 \ \vee t \in T \quad (10)$$

$$x_{p,t,a,a'} \in [0,1] \ \vee p \in P, t \in T, a \in A, a' \in A \quad (11)$$

$$x_{p,t,a,a'} + x_{p',t,a,a'} \leq 1 \quad (12)$$
$$\vee t \in T, \ a \in A$$

Monte Carlo Simulation

Algorithm generates random scenario and find optimal solution for that scenario

Do this for many scenarios – aggregate into a distribution

Given distribution, use a heuristic to select "best" option

Enterprise System Planning Algorithm

Projects and architecture are input

Define real options on each project

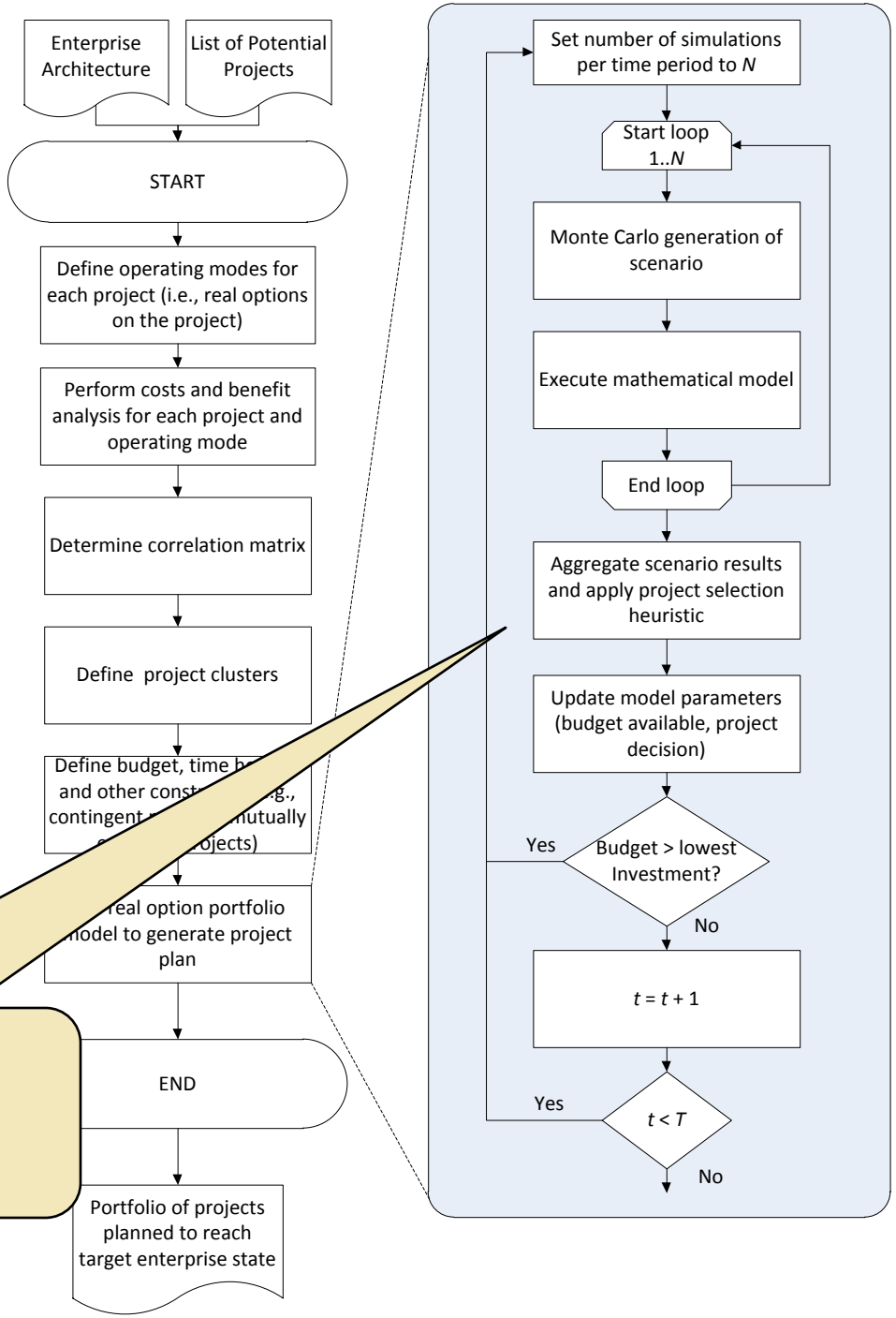
Cost/benefit analysis for each operating mode

Projects correlation in portfolio

Cluster projects via goals

Define constraints (budget/year, resources)

Do *N* Monte Carlo simulations using discrete stochastic options optimization model – aggregate results and *apply heuristic*



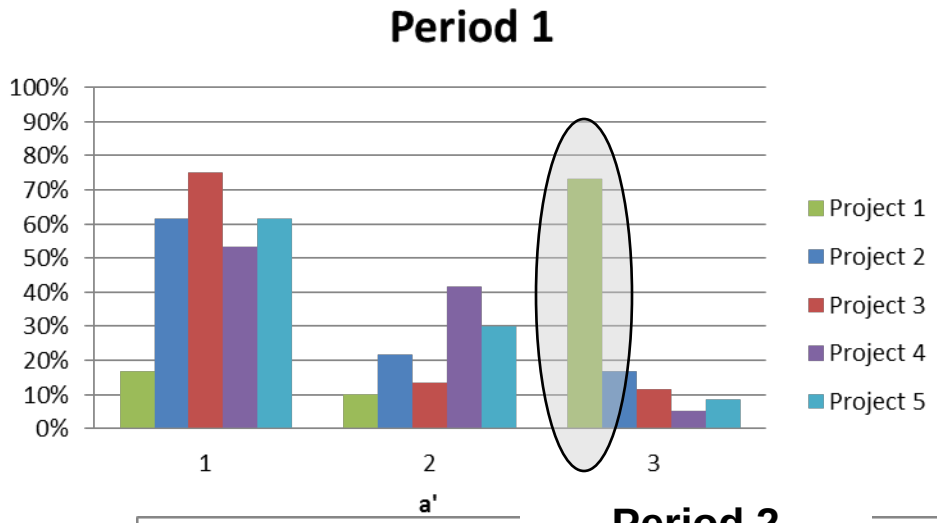
Input Data

Small Defense Contractor – low-volume, high-mix manufacturer of electro-mechanical systems

			Ipaa'			Random Variable			
			a1	a2	a3	θp,1,1	F	VC	σp
P1	a1	Maintain current organization of functional departments (i.e., delay)	0	0.8	1.2	4	0	0.9	0.7
	a2	Reorganize into program groups	0.2	0	0.2	4	0.2	1	
	a3	Expand reorganization to marketing and other departments	0.3	0.1	0	4	0.3	1.2	
P2	a1	delay	0	0.6	0.7	0.35	0	0	0.15
	a2	COTS -- local	0	0	0.1	0.35	0	1	
	a3	Option for HR, CRM, and ERP (growth)	0	0	0	0.35	0	1.1	
P3	a1	delay	0	0.45	0.55	0.3	0	0	0.3
	a2	SolidWorks upgrade to SW Simulation Premium for	0.05	0	0.08	0.3	0	1	
	a3	Pro-E	0.05	0.05	0	0.3	0	1.1	
P4	a1	delay	0	0.76	1	0.6	0	0	0.25
	a2	ADP-EZ Payroll (Payroll)	0.1	0	0.15	0.6	0	1	
	a3	ADP -- EZ Labor (labor hr tracking)	0.1	0.1	0	0.6	0	1.2	
P5	a1	delay	0	0.2	0.45	0.1	0	0	0.08
	a2	DOORS or Requirement Mgmt Tool	0	0	0.22	0.1	0	0.8	
	a3	CORE Requirement Mgmt Tool	0	0	0	0.1	0	0.9	

(notional cost and benefit data)

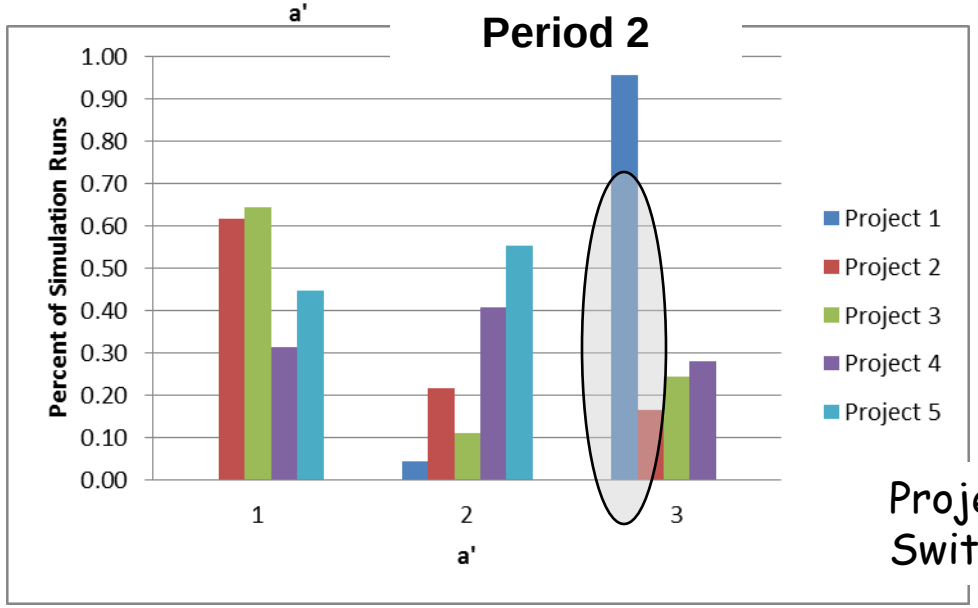
Results – Best First Heuristic



$$x_{ptaa'}$$

$$x_{1113} = 1$$

Project #1, in time period #1
Switch to operating mode 3



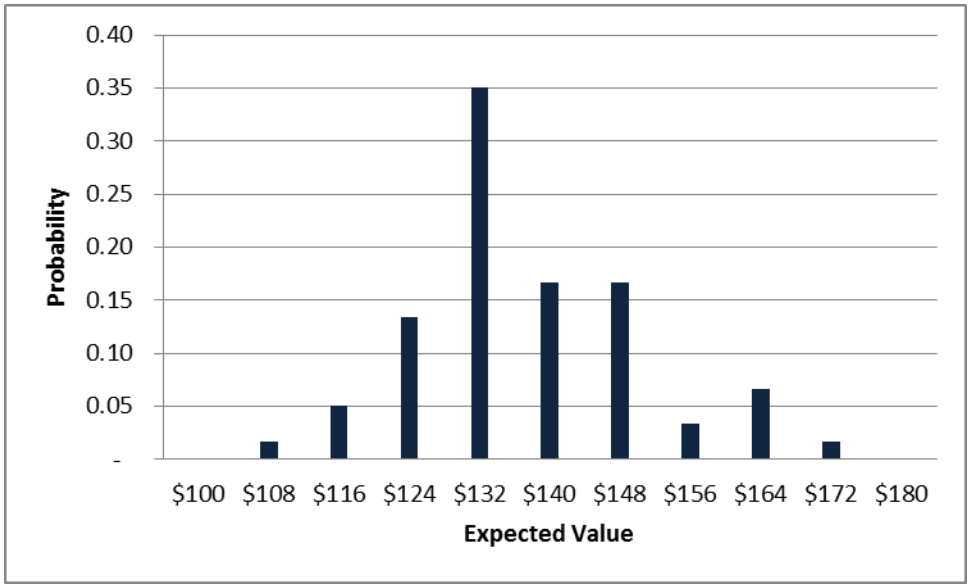
$$x_{5212} = 1$$

$$x_{4212} = 1$$

Project2 #4 and #5, in time period #2
Switch to operating mode 2

Time Horizon Results

Expected Value, assuming optimal decisions



The entire distribution of possible outcomes influences decisions, not just the expected value

Risk-informed decision making

Each year, as uncertainty is resolved (what happened during the past year?) – redo plan going forward and revise plans according to new information.

Future Work

- Applicability to the warfighter side of DoD that is non-financial and driven more by ***acquisition of capabilities*** via evolutionary acquisition process

- Model is intractable for realistic size problems, opportunity for improvement in algorithm over the heuristic approach, or experiment with different heuristics

- Opportunities to investigate real options ***designed IN*** the architecture versus real options ON the project

Conclusions

- ***Motivation:*** Flexibility is being left on the table – rethink projects and system architectures in terms of "options" can help recapture and use this flexibility
  - Decision makers do think about these types of options, but the informal approach may miss options, is not based on valuation, and human cognitive limits in evaluating multiple projects/options concurrently
- Broad-based Method
  - Need flexible methods
  - Need means to predict enterprise architecture performance
  - Need means to plan EA evolution as series of projects / real options
- Model goes hand-in-hand with evolutionary acquisition of capabilities
- Design EA in terms of modules to implement real options in planning
- Consider a project portfolio because decisions are inter-related