Acquisition Research Program:
Creating Synergy for Informed Change

Advanced Capability Builds for Aegis:
Stochastic Portfolio Optimization (Selection and Prioritization), Risk Simulation, KVA, and Strategic Real Options

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Introduction and Context

- **Introduction of Open Architecture (OA) business and technical processes provides opportunity to improve acquisition**
  - **Increased competition**
  - **Shorter cycle time**
  - **Reduced total ownership and acquisition cost**
- **The AEGIS Advanced Capability Build (ACB) process is one implementation of the OA approach**

The ACB Process

- The ACB process provides for software updates to ships within the program on a two-year cycle
- ACBs are identified by the first year in which they will be fielded, e.g., ACB-14
- US Navy CGs and DDGs will be inducted into the process as they receive computing plant updates during major availabilities that convert the processors and networks to a COTS-based configuration
- The hardware baseline that supports OA must be in place to begin execution of the ACB process
- Once a ship is inducted, it will receive the scheduled update plus any previous updates (e.g., ACB 16 ships entering the program will receive ACB 14 capabilities as well)

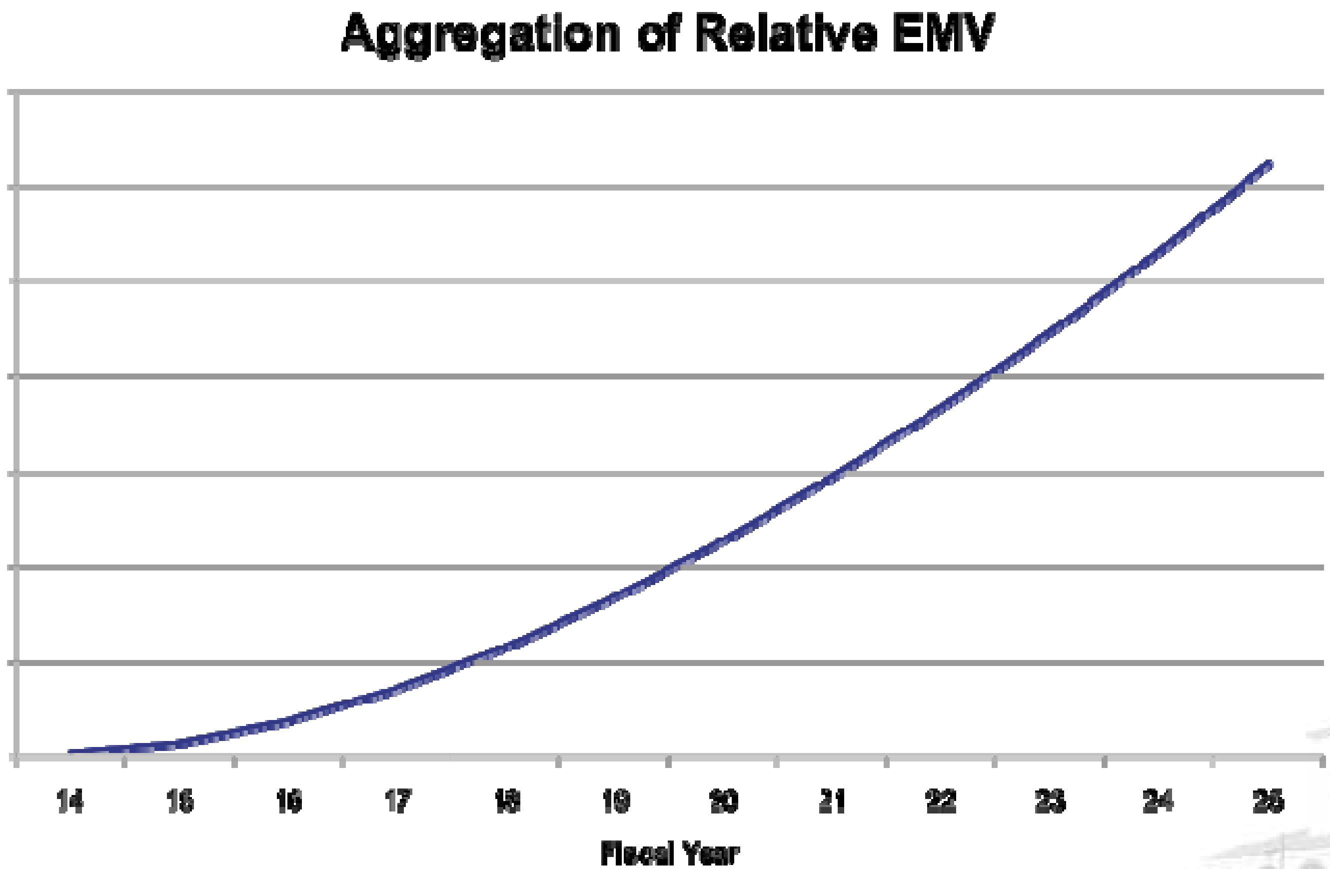
The problem addressed in this study deals with risk and value

- Value is realized through fielding of military capability for the war-fighter
- Risk is found in uncertainty
  - Cost uncertainty creates budget risk
  - Technology risk can lead to schedule and budget risk
- This study provided a pilot implementation of the Knowledge Value Added + Integrated Risk Management method to represent value and risk to assist the PM and sponsor in selecting the proper capability mix to field in a given ACB
- The problem space considered 23 capabilities to be implemented through changes to 32 software components across three scheduled ACBs (ACB 14, 16, and 18)
- Given the universe of desired capabilities, the problem is to select those providing the best value to the war-fighter for inclusion in a given ACB subject to budget constraints, risk and uncertainty of cost and timing

The study articulated a notional value of military value and used powerful financial and analytical tools

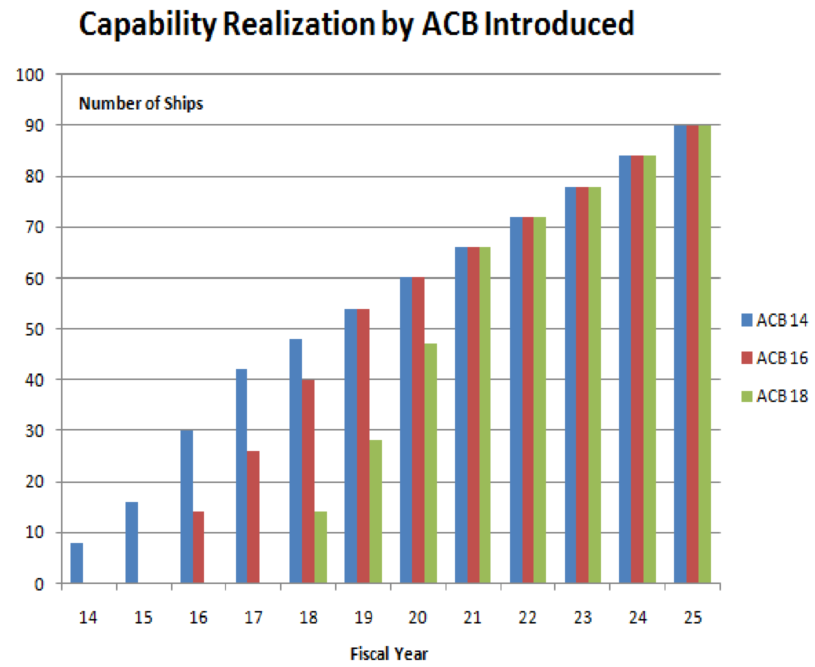
- Knowledge Value Added (KVA) provides ways of representing outputs (value) in common units
- Real Options provides tools to compare the value stream of various options in rigorous terms
- Integrated Risk Management considers uncertainties and represents risk in quantitative, clear and defensible terms

As ships enter the program and ACBs are executed, military value is additive



One advantage of the ACB process is the "catch-up" effect

- The ACB process helps manage risk by allowing the PM and sponsor to delay introduction of a particular capability until it is ready without waiting many years for the next cycle
- A delay until the next ACB is more acceptable because within five years the number of ships with the capability will be the same



The remainder of this presentation discusses the analysis and results

- Assumptions and constraints
- Measurement of military value (KVA)
- Application of Real Options and Integrated Risk Management (IRM) to the selection of capabilities

Assumptions and Constraints

- The study applied the following initial assumptions
  - The capabilities were independent of each other
  - Capabilities were implemented through changes to modules within the objective architecture
- Initial constraints assumed
  - A notional ***integration*** budget of $150 million per ACB
  - All uncertainty estimates for the initial model were based on cost volatility
- Future study will include
  - Effects of interdependencies (nested options), correlations, diversification
  - Schedule risk
  - Opportunity cost and penalty costs of abandonment

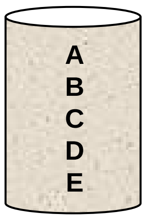
Measuring Value

- KVA **quantifies the value** of the knowledge used to produce common units of output
- Shows decision makers the **benefit and cost** of each program or project
- Measures how resources are allocated on the volatility of productivity (e.g., ROI)
- **Providing ROI volatility inputs to IRM**
- **Military value** in this study was postulated to be represented by capability provided to the warfighter measured in a variety of ways
  - Strategic importance as represented by OPNAV sponsor priorities
  - Technical value as represented by acquisition community priority
  - Functional complexity represented by Delivered Source Lines of Code (DSLOC)
  - Subject Matter Expert evaluation of complexity and mission criticality, aggregated from the component level

Integrated Risk Management Process

1 List of projects and strategies to evaluate

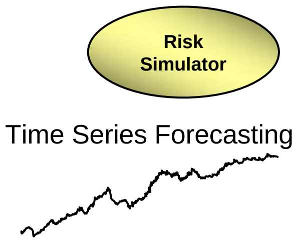
RISK IDENTIFICATION



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

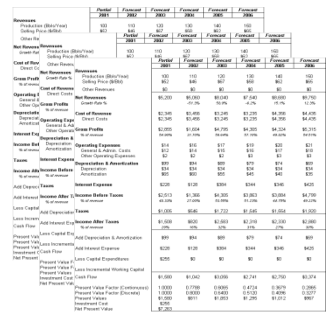
RISK PREDICTION



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

3 Develop static financial models

RISK MODELING

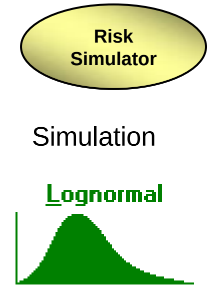


Traditional analysis stops here!

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

4 Dynamic Monte Carlo simulation

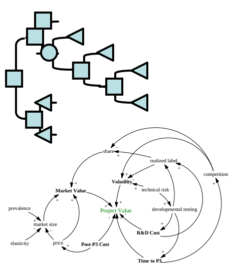
RISK ANALYSIS



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

5 Framing Real Options

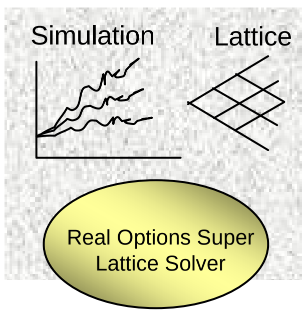
RISK MITIGATION



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

6 Options analytics, simulation, optimization

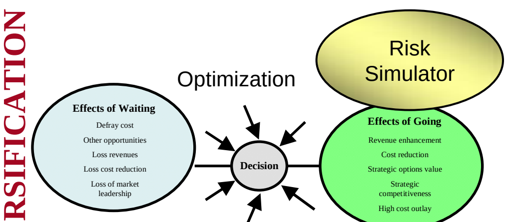
RISK HEDGING



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

7 Portfolio optimization and asset allocation

RISK DIVERSIFICATION



…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

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

KVA+RO+IRM are a combination of method and toolset to assist the PM in decision making

- Knowledge Value Added (KVA) is a method that systematically expresses non-revenue activities in common units of output to quantify value
- Real Options (RO) provides a way to qualitatively and quantitatively evaluate the relative value of various courses of action under consideration
- Integrated Risk Management combines KVA and RO with a powerful toolset to assist the program manager in the decision process
- Treatment of parameters as distributions permits rigorous analysis in an uncertain world, where instead of single point estimates, we use ranges as inputs
- Monte Carlo risk simulation and process models permit consideration of all possible outcomes within a reasonable time period
- Disciplined processes yield defensible results that can be updated as more knowledge/ information is realized by the program
- Risk simulation, sensitivity analysis, and forecasting are automated (analyses are efficient, quick, consistent, replicable, defensible, and scalable)

The toolset and method provide a way for the PM to determine the relative merits of the various options available, to make informed choices based on value streams and risk, and then to articulate those choices to the sponsor and the acquisition chain of command.

Model input assumptions are entered on a data sheet

Common sizing inputs and using weights to obtain the expected military value

Actual Capabilities Redacted

Cost Data Redacted

Capability	High	Mid	Low	SME Mean Value Added	Technical Priority	OPNAV Priority	DSLOC Complexity	Cost Simulation	Technical Priority H-L	OPNAV Priority H-	SMEVA and DSLOC Only EMV Score	All Weighted & Common Sized EMV Score	OPNAV & Technical Priority EMV Score	Objective Used	CV
Common Size Factor				1.00			0.10		2.00	2.00					
Weighting Scheme				35%			35%		15%	15%					
Capability 1				43.00	3	2	278	29.00	21	22	321.00	37.68	43.00	43.00	0.1834
Capability 2				28.00	2	1	541	126.00	22	23	569.00	42.24	45.00	45.00	0.0903
Capability 3				13.00	1	3	58	77.00	23	21	71.00	19.78	44.00	44.00	0.0719
Capability 4				40.33	5	4	635	21.00	19	20	675.33	48.04	39.00	39.00	0.0576
Capability 5				17.67	7	7	134	15.00	17	17	151.67	21.07	34.00	34.00	0.0407
Capability 6				35.67	4	6	392	27.00	20	18	427.67	37.60	38.00	38.00	0.1568
Capability 7				50.67	6	5	549	17.00	18	19	599.67	48.05	37.00	37.00	0.0481
Capability 8				47.67	10	11	675	77.00	14	13	722.67	48.41	27.00	27.00	0.0689
Capability 9				19.00	8	8	109	16.00	16	16	128.00	20.07	32.00	32.00	0.0382
Capability 10				33.67	11	9	189	10.00	13	15	222.67	26.80	28.00	28.00	0.0603
Capability 11				20.00	9	10	88	3.00	15	14	108.00	18.78	29.00	29.00	0.0707
Capability 12				27.67	14	12	159	21.00	10	12	186.67	21.85	22.00	22.00	0.1137
Capability 13				27.67	12	13	159	11.00	12	11	186.67	22.15	23.00	23.00	0.0408
Capability 14				44.67	13	14	523	27.00	11	10	567.67	40.24	21.00	21.00	0.0956
Capability 15				17.67	20	15	134	10.00	4	9	151.67	14.77	13.00	13.00	0.0603
Capability 16				17.67	21	16	134	5.00	3	8	151.67	14.17	11.00	11.00	0.0816
Capability 17				34.33	19	17	328	9.00	5	7	362.33	27.10	12.00	12.00	0.0454
Capability 18				17.67	22	18	134	6.00	2	6	151.67	13.27	8.00	8.00	0.0372
Capability 19				14.00	23	19	81	18.00	1	5	95.00	9.54	6.00	6.00	0.0340
Capability 20				17.67	15	20	134	14.00	9	4	151.67	14.77	13.00	13.00	0.0164
Capability 21				22.67	18	21	144	18.00	6	3	166.67	15.67	9.00	9.00	0.0454
Capability 22				11.67	16	22	180	78.00	8	2	191.67	13.38	10.00	10.00	0.0468
Capability 23				10.00	17	23	95	10.00	7	1	105.00	9.23	8.00	8.00	0.0603

Starting with 23 capabilities (more to be added later when there is sufficient data)

High, most likely, low cost estimates for running thousands of simulation trials

Technical and OPNAV priorities

DSLOC provides a measure of complexity

Intermediate computations: risk-simulation assumption, readjusted priorities, expected military score and cost-based risk coefficients

Running the model provides recommended selections

ACB 14 sample results with $150M budget constraint

Expected Military Value: SME Mean Value Added, DSLOC Complexity, Common Sized, Weighted OPNAV/Technical Priorities

Selection of EMV calculation method

Reset

Actual Capabilities Redacted

Cost Data Redacted

Capability	EMV	Cost	Risk $	Risk %	Selection
Capability 1	37.68		$6.91	18.34%	0.0000
Capability 2	42.24		$3.81	9.03%	0.0000
Capability 3	19.78		$1.42	7.19%	0.0000
Capability 4	48.04		$2.77	5.76%	1.0000
Capability 5	21.07		$0.86	4.07%	1.0000
Capability 6	37.60		$5.90	15.68%	0.0000
Capability 7	48.05		$2.31	4.81%	1.0000
Capability 8	48.41		$3.34	6.89%	0.0000
Capability 9	20.07		$0.77	3.82%	1.0000
Capability 10	26.80		$1.62	6.03%	1.0000
Capability 11	18.78		$1.33	7.07%	1.0000
Capability 12	21.85		$2.48	11.37%	0.0000
Capability 13	22.15		$0.90	4.08%	1.0000
Capability 14	40.24		$3.85	9.56%	1.0000
Capability 15	14.77		$0.89	6.03%	1.0000
Capability 16	14.17		$1.16	8.16%	1.0000
Capability 17	27.10		$1.23	4.54%	1.0000
Capability 18	13.27		$0.49	3.72%	1.0000
Capability 19	9.54		$0.32	3.40%	0.0000
Capability 20	14.77		$0.24	1.64%	0.0000
Capability 21	15.67		$0.71	4.54%	0.0000
Capability 22	13.38		$0.63	4.68%	0.0000
Capability 23	9.23		$0.56	6.03%	0.0000
Max EMV — Total	314.51	$150.00	$6.18		
Constraints:	MAX	$150.00			

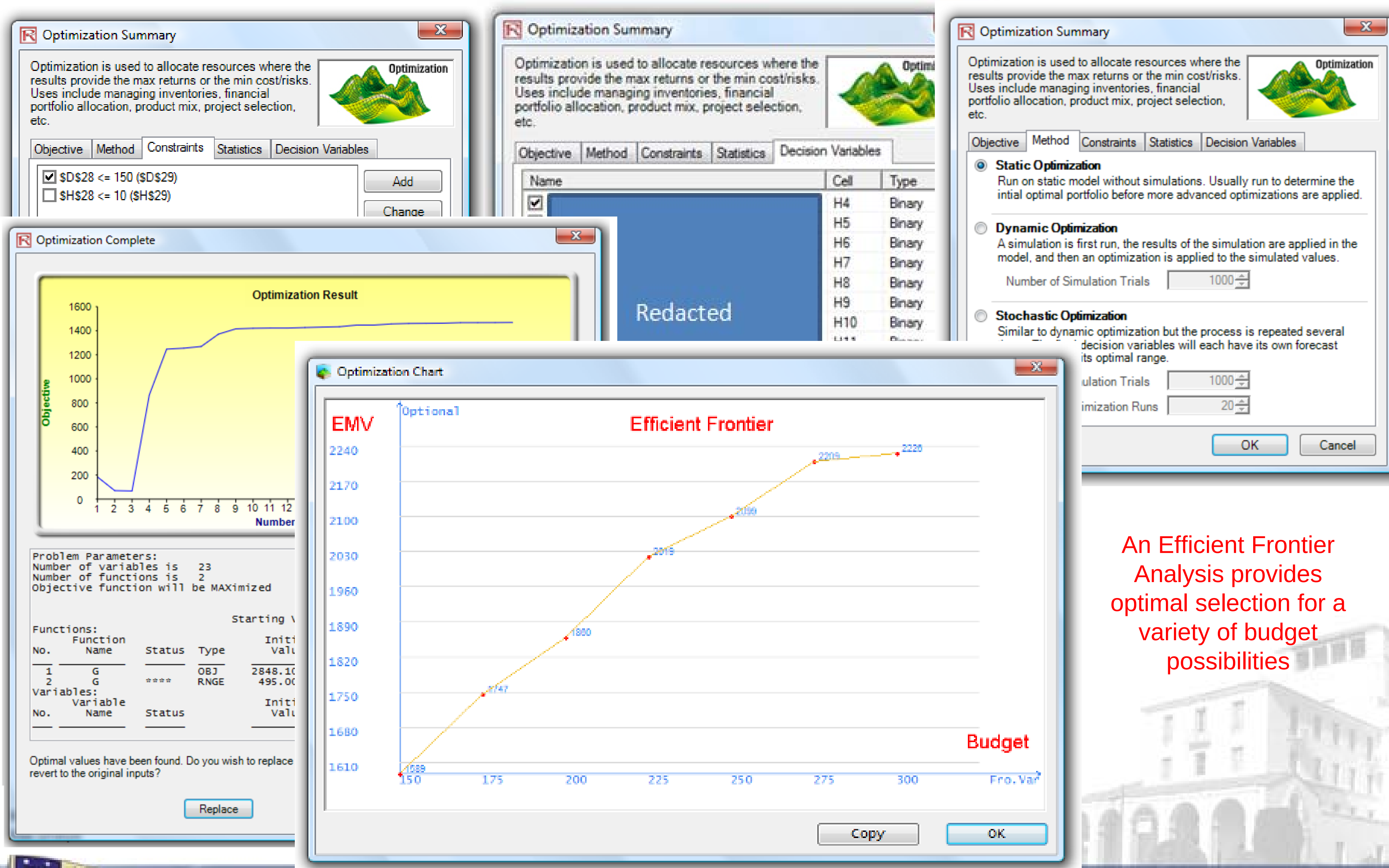
Go or No-Go decisions in the portfolio selection

Benefits (EMV), Cost, Risk are considered

Constraints can be set (budget, capability count, FTE, priorities, etc)

Starting with 23 capabilities (more to be added later when there is sufficient data)

Portfolio optimization analysis gives a set of solutions



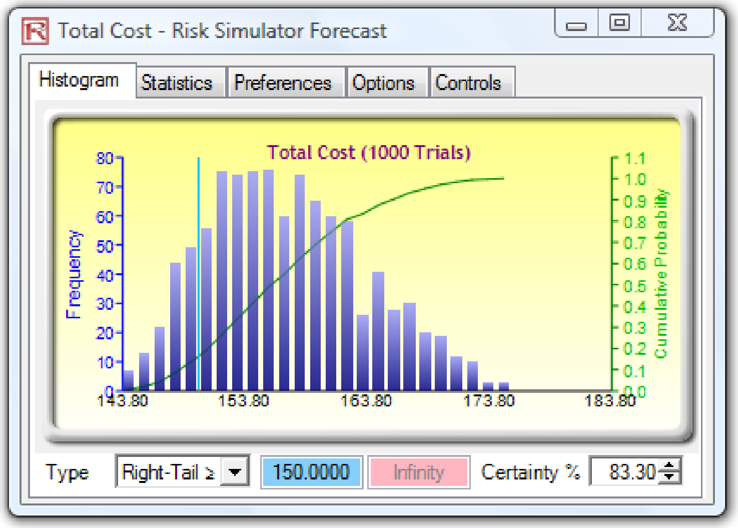
An Efficient Frontier Analysis provides optimal selection for a variety of budget possibilities

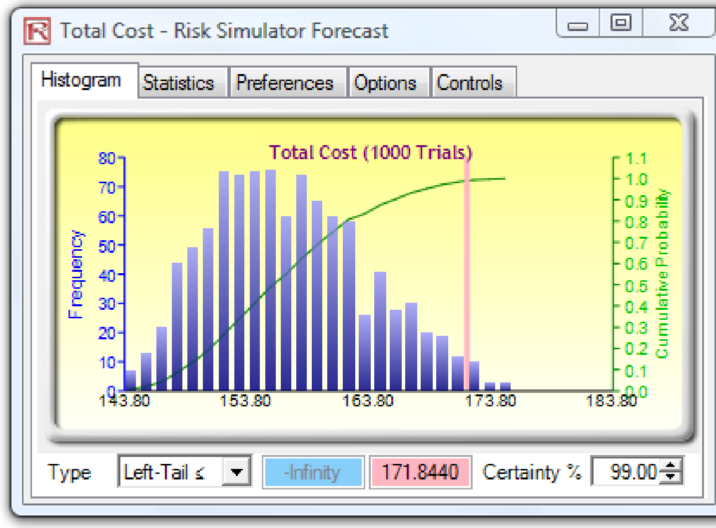
Risk simulation of cost provides the decision maker with additional data

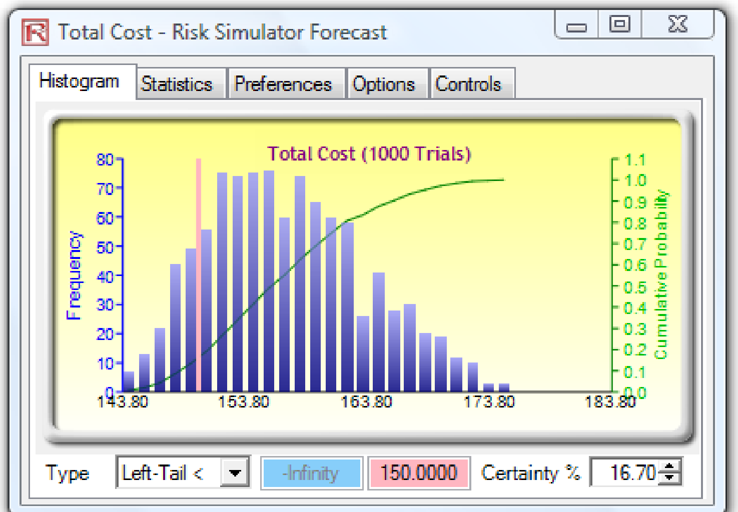
Risk analysis and 100,000 simulation trials on cost estimations…

We can determine the probability that ACB-X will exceed the $150M budget, determine what $171M will yield a 99% certainty of sufficient budget to cover all costs

We also looked at the optimal portfolio given a 90% probability that $150M will be enough







Total Cost - Risk Simulator Forecast

Histogram | Statistics | Preferences | Options | Controls

Statistics	Result
Number of Trials	1000
Mean	156.5740
Median	155.8994
Standard Deviation	6.4490
Variance	41.5891
Coefficient of Variation	0.0412
Maximum	174.9497
Minimum	142.9728
Range	31.9769
Skewness	0.3655
Kurtosis	-0.4648
25% Percentile	151.6747
75% Percentile	160.8706
Percentage Error Precision at 95% Confidence	0.2553%

*Screen shots from Risk Simulator software

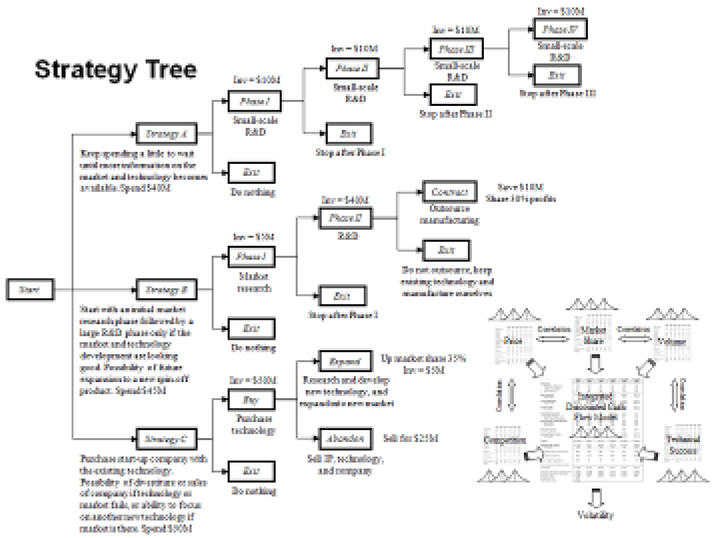
Optimized portfolios are time-sequenced and risks are quantified

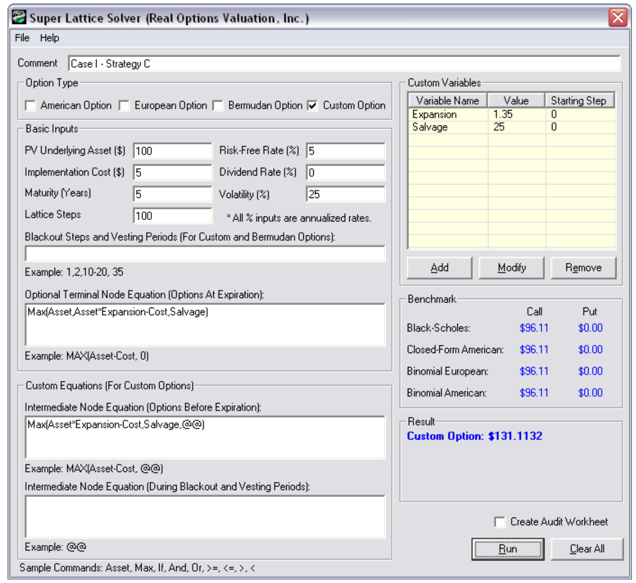
Actual Capabilities Redacted

Capability	Optimal on Budget	Optimal Cost-Risk	Must-Have	Cost-Risk
Capability 1	ACB16	ACB16	ACB16	ACB18
Capability 2	ACB18	Later	ACB14	ACB14
Capability 3	Later	Later	Later	Later
Capability 4	ACB14	ACB14	ACB16	ACB16
Capability 5	ACB16	ACB14	ACB16	ACB16
Capability 6	ACB14	ACB16	ACB18	ACB18
Capability 7	ACB14	ACB14	ACB16	ACB16
Capability 8	Later	ACB18	ACB18	Later
Capability 9	ACB16	ACB14	ACB18	ACB16
Capability 10	ACB14	ACB14	ACB16	ACB16
Capability 11	ACB14	ACB14	ACB14	ACB14
Capability 12	ACB16	ACB16	ACB18	ACB18
Capability 13	ACB14	ACB14	ACB16	ACB16
Capability 14	ACB14	ACB14	ACB16	ACB16
Capability 15	ACB14	ACB16	ACB16	ACB18
Capability 16	ACB14	ACB14	ACB14	ACB16
Capability 17	ACB14	ACB14	ACB14	ACB16
Capability 18	ACB14	ACB14	ACB14	ACB16
Capability 19	ACB16	ACB18	Later	Later
Capability 20	ACB16	ACB16	Later	ACB18
Capability 21	ACB16	ACB16	Later	ACB18
Capability 22	Later	Later	Later	Later
Capability 23	ACB16	ACB16	ACB16	ACB18

ACB 14 + ACB 16 + ACB 18 *rounded to the nearest 0.1	Optimal on Budget	Optimal Cost-Risk	Must-Have	Cost-Risk
Total Capabilities ACB14	11	11	5	2
Total Capabilities ACB16	8	7	9	10
Total Capabilities ACB18	1	2	4	7
EMV ACB14	310.98	299.74	115.56	61.02
EMV ACB16	149.87	151.58	268.03	280.96
EMV ACB18	42.24	57.94	127.93	151.58
Total Cost ACB14	$146.00	$139.00	$149.00	$129.00
Total Cost ACB16	$141.00	$129.00	$150.00	$137.00
Total Cost ACB18	$126.00	$95.00	$141.00	$129.00
Total Spent on ACB14-18	$413.00	$363.00	$440.00	$395.00
Probability of Under Budget ACB14	29.70%	97.90%	41.50%	90.80%
Probability of Under Budget ACB16	72.23%	90.90%	16.25%	99.90%
Probability of Under Budget ACB18	94.80%	99.90%	72.90%	90.90%
ACB14 Median 50th Percentile on Budget	$153.20	$142.90	$152.60	$132.30
ACB14 Median 85th Percentile on Budget	$160.22	$146.60	$166.60	$146.30
ACB14 Median 95th Percentile on Budget	$164.30	$148.70	$173.90	$153.50
ACB16 Median 50th Percentile on Budget	$145.40	$137.90	$156.50	$139.50
ACB16 Median 85th Percentile on Budget	$153.50	$147.30	$164.80	$143.30
ACB16 Median 95th Percentile on Budget	$157.80	$152.70	$169.20	$145.30
ACB18 Median 50th Percentile on Budget	$128.90	$95.30	$145.10	$137.90
ACB18 Median 85th Percentile on Budget	$142.90	$101.30	$153.50	$147.30
ACB18 Median 95th Percentile on Budget	$150.20	$104.30	$158.40	$152.70

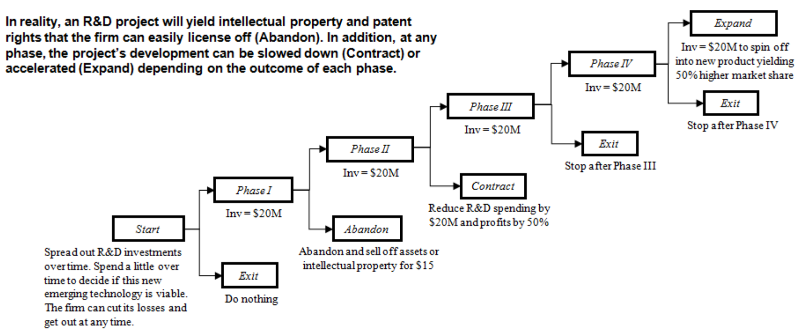
More complex options and constraints can be accommodated in the analyses





Inclusion of Analysis of Alternatives or Courses of Action using strategic real options analysis of various implementation pathways, suitable for nested and path dependent options (some components and capabilities are interdependent)

Strategy Tree
(Complex Multi-Stage Development)



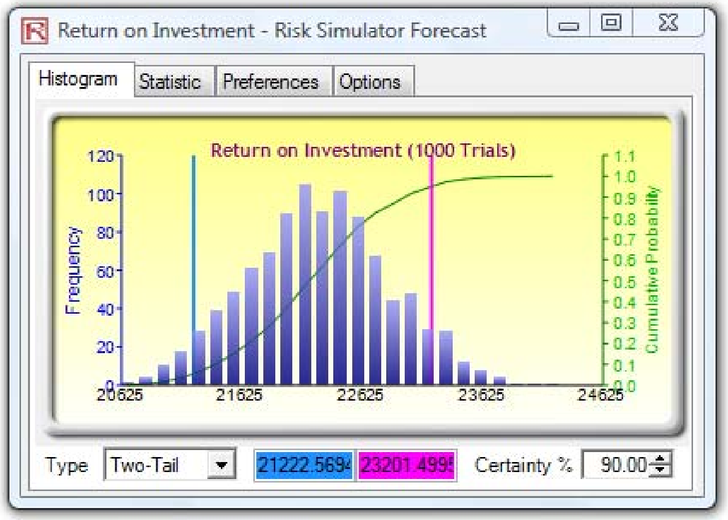
- Risk can be mitigated or planned for though
  - Budgeting to the amount that the simulator reveals is necessary to provide a given level of risk
  - Improving cost estimate quality and reducing volatility
  - Up-front action to change the cost equation
    - Contractual limits on cost through use of fixed price or other contract vehicles to shift risk with the vendor
    - Incentives to the contractor that reward for success and penalize for failure to meet cost targets
- Capability selection can also be accomplished by applying risk constraints during the optimization

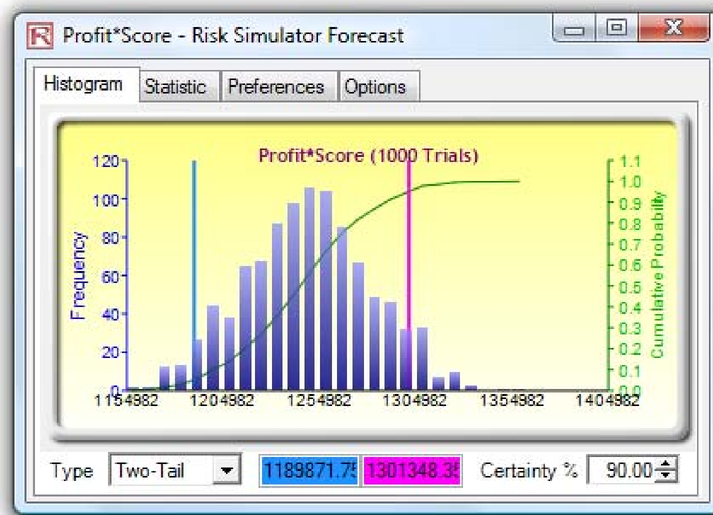
Going forward

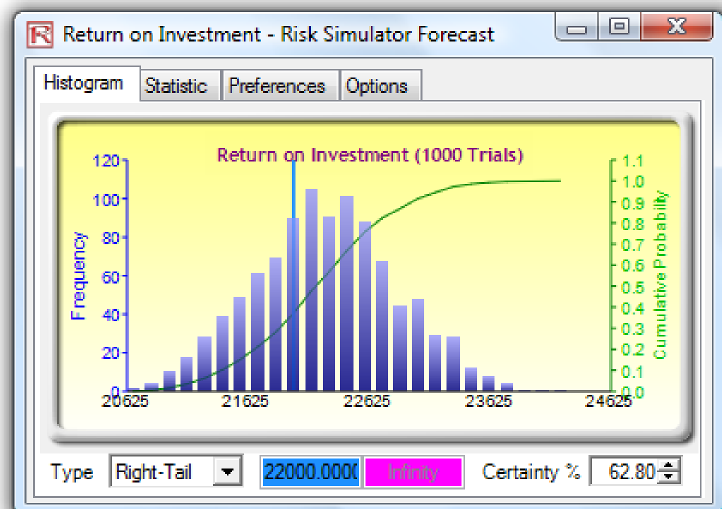
- More complex analyses to determine which optimization portfolio to choose
  - nested and mutually exclusive options among and between various capabilities
  - expansion options of a base capability into additional capabilities
- Strategic real options approach to generate different implementation pathways
  - provide strategic option trees
  - identify best decision strategic option pathway

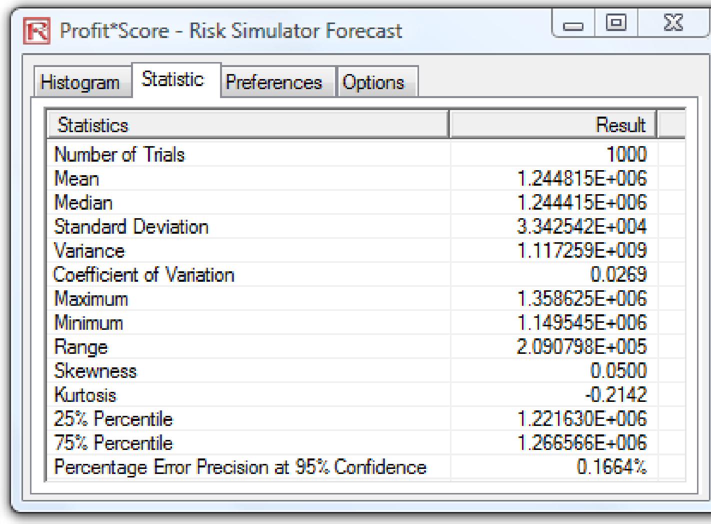
Back up slides

Risk Simulation (Risk Management) shows the range of likely outcomes









Statistics	Result
Number of Trials	1000
Mean	1.244815E+006
Median	1.244415E+006
Standard Deviation	3.342542E+004
Variance	1.117259E+009
Coefficient of Variation	0.0269
Maximum	1.358625E+006
Minimum	1.149545E+006
Range	2.090798E+005
Skewness	0.0500
Kurtosis	-0.2142
25% Percentile	1.221630E+006
75% Percentile	1.266566E+006
Percentage Error Precision at 95% Confidence	0.1664%

Risk Analytics (sensitivity, tornado, fitting, and many other analytical tools) provide depth of understanding