Assessing the Impact of Confidence Levels in Funding and Budgeting NASA Science Missions

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Agenda

- Background
  - *Overview*
- Approach
  - *Methodology*
  - *Data input*
- Results
  - *Figures of Merit*
  - *Scenario 1: Typical Portfolio Mix*
  - *Scenario 2: All Projects Equal*
  - *Scenario 3: Single Project Flagship*
- Summary

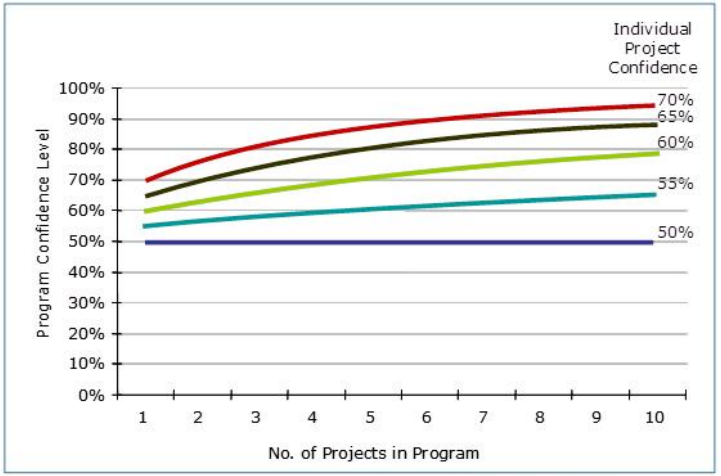
Portfolio Analysis Review

- In finance, the “portfolio effect” is defined as the tendency for the risk on a well-diversified holding of investments to fall below the risk of most and sometimes all of its individual components
- Using the portfolio principles, individual project confidence levels can roll up to higher or lower confidence levels at the program level
- Applied to an Agency’s mission portfolio, the portfolio effect can be applied to understanding the relationship between confidence at the Agency’s (or Program’s) level and confidence at individual project level
- For the portfolio effect to work, projects within a program (within a portfolio) that turn out not to require their entire original budget must be *managed in such a way that their unused budget is available to other projects*
- These unneeded resources are then available to be used for projects which exceeded their budgets.

Decision makers can fund projects at lower confidence levels while achieving higher confidence levels from an Agency or Program viewpoint (Anderson, 2004)

Portfolio Analysis – NASA Implementation

- The portfolio effect was one of the primary drivers to NASA's original probabilistic cost policy implementation (Hamaker, 2006)
  - *Original policy was cost confidence only and did not address schedule confidence*
  - *Assumed max portfolio effect*
- With the implementation of Joint Cost and Schedule Confidence Level, consideration and dialog of portfolio analysis was not a driving factor in policy CLs (70th and 50th percentiles), (Coonce, 2009)
  - *Driving factor was including schedule*
  - *70th percentile was adopted from previous policy*
  - *50th percentile was adopted to give the projects a 50/50 chance*
  - *NASA set up a tiered system to help account and incentivize portfolio behavior*



NASA Policy can enable portfolio behavior

NASA Probabilistic Policy in a Nutshell

- **At KDP-B**
  - *Projects must generate a low and high **cost and schedule** estimates with associated probabilities of completing at or below those costs/dates*
  - *An independent SRB will evaluate project-generated results*
  - *Decision authority will decide upon the low and high cost and schedule targets. Goal is to set budgets at a higher probability of success in order to give projects a better chance of success at KDP-C*
- **At KDP-C**
  - *Projects must generate a cost-loaded schedule and **produce a JCL** that is executable within the baseline commitments*
  - *An independent SRB will evaluate the project-generated JCL results and model*
  - *Decision Authority will decide the JCL (probability) for the associated development and life cycle cost at which the agency commits to deliver the project*

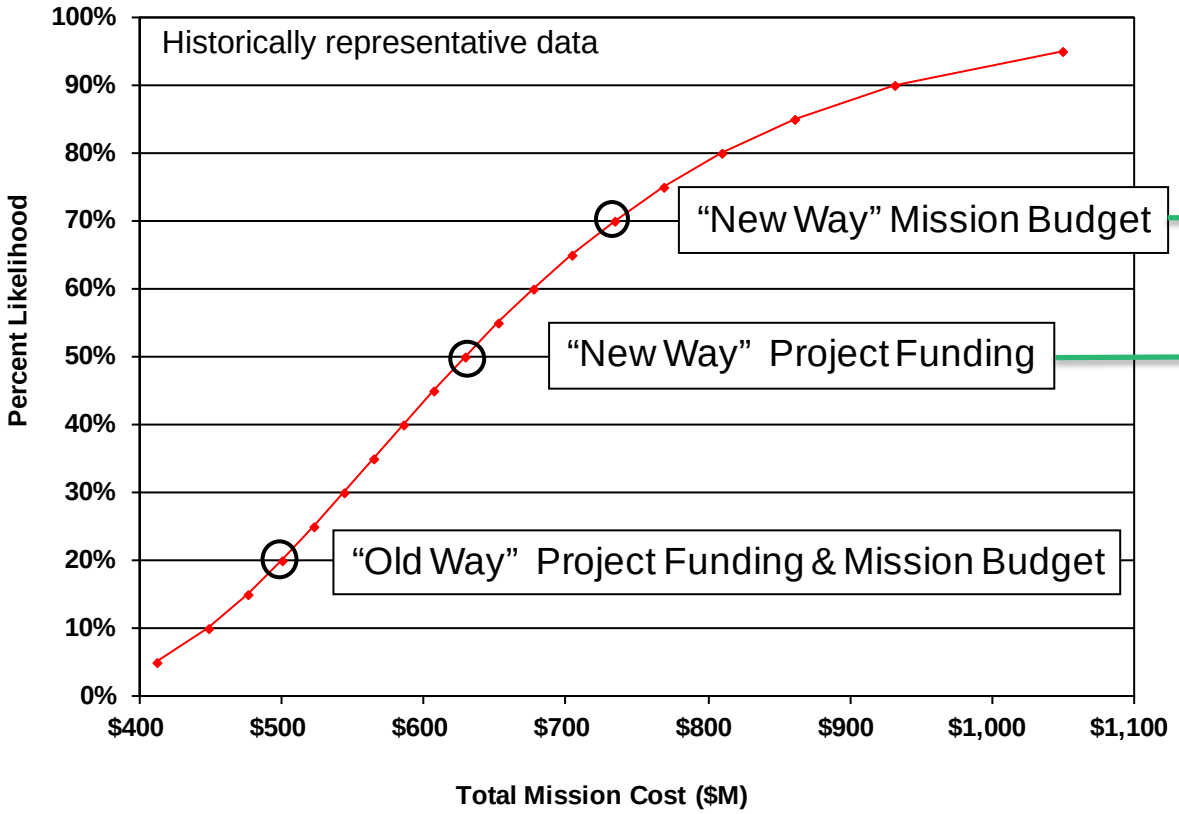
KDP 1 / KDP C POLICY

- *"Mission Directorates shall **plan and budget** tightly coupled and single-project programs (regardless of life-cycle cost) and **projects with an estimated life-cycle cost greater than $250 million based on a 70** percent joint cost and schedule confidence level, or as approved by the Decision Authority."*
- *"Any JCL approved by the Decision Authority at less than 70 percent shall be justified and documented."*
- *"Mission Directorates shall ensure funding for these projects is consistent with the **Management Agreement** and in no case less than the equivalent of a **50 percent JCL**."*

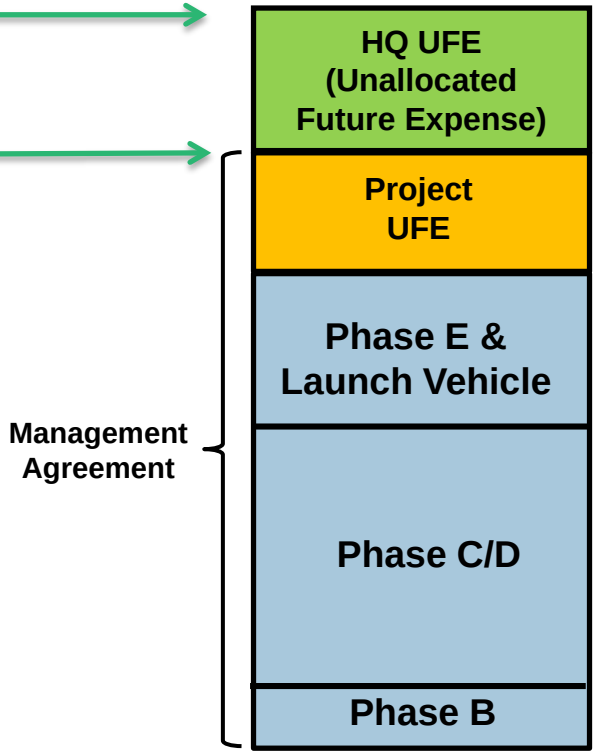
Source: NPR 7120-5E. Section 2.4.4

Simple Question – Is this a Good Thing?

Assessment of Optimum Confidence Levels for SMD Mission Portfolio



Life Cycle Cost Estimate At KDP C = Agency Baseline Commitment



Is Budgeting at the 70th Percentile while Funding the Project at the 50th Percentile Beneficial? It depends!

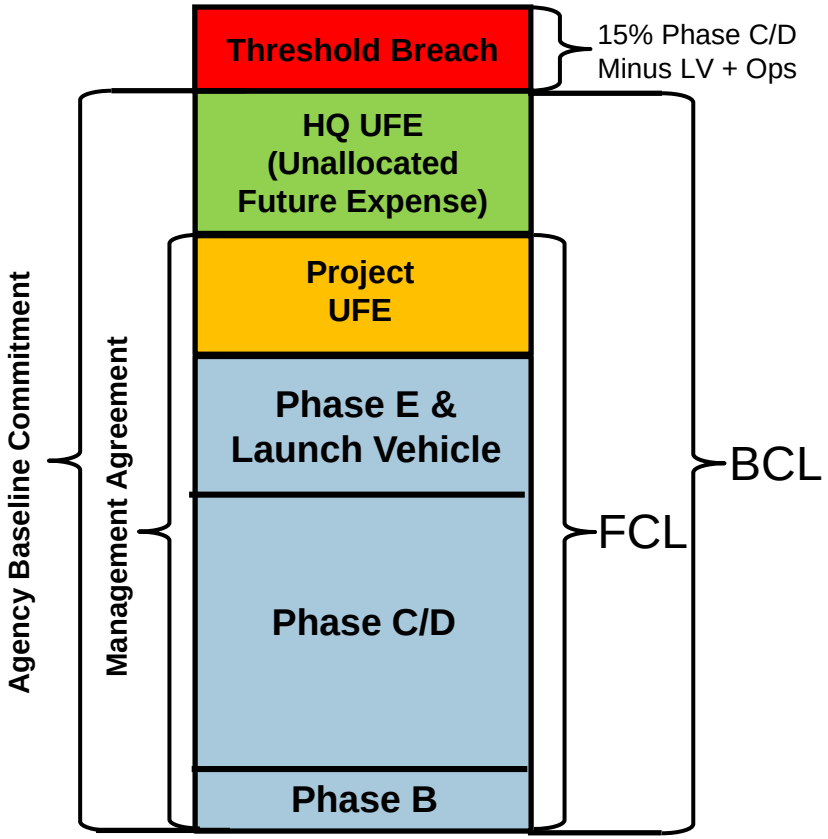
Portfolio Effect vs Moral Hazard

- Risk compensation, or moral hazard, is when people tend to adjust their behavior in response to perceived level of risk
- Examples:
  - *Studies show that drivers' response to antilock brakes is to drive faster, follow closer and brake later, accounting for the failure of ABS to result in any measurable improvement in road safety*
  - *After purchasing automobile insurance, some may tend to be less careful about locking the automobile or choose to drive more, thereby increasing the risk of theft or an accident for the insurer*
- How does this apply to NASA CL policy? A key assumption in analysis is that projects will not give back their unused budget/schedule to the program/Agency – *this assumption counteracts the portfolio effect – but by how much?*
- Layman's terminology: "gold plating", self-fulfilling prophecy, more testing to ensure technical success

If funded at higher confidence levels, projects will tend to spend all available funds

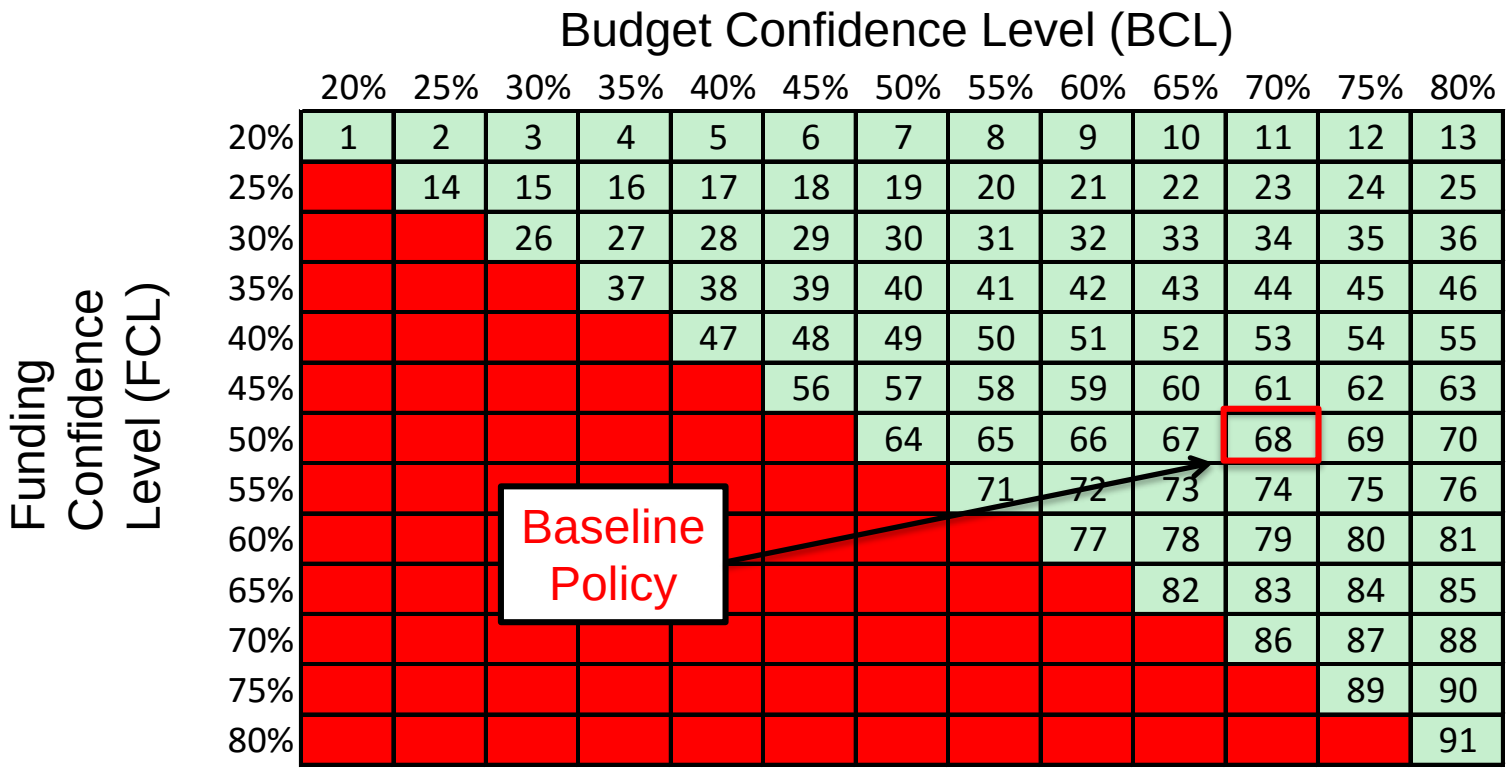
Definition of Terms

- BCL = Budgeting Confidence Level
  - *Confidence level at which the project is budgeted – i.e. commitment level*
  - *Includes both HQ UFE and Project UFE*
  - *Current policy is 70%*
- FCL = Funding Confidence Level
  - *Confidence level at which project is funded*
  - *Includes only Project UFE*
  - *Current policy is 50%*
- Life Cycle Cost (LCC) = BCL
  - *Includes Phase B-E cost including Launch Vehicle*
- Threshold Breach Value
  - *15% over development funding (Phase C/D)*
  - *15% * Phase C/D + LCC*



Study Case Matrix

- Basic case matrix consists of 91 separate cases
- Each BCL requires a separate scenario to be developed so that project planned start dates can be changed to “pack in” the missions at a given funding level
- Each FCL within a BCL only requires that mission funding change



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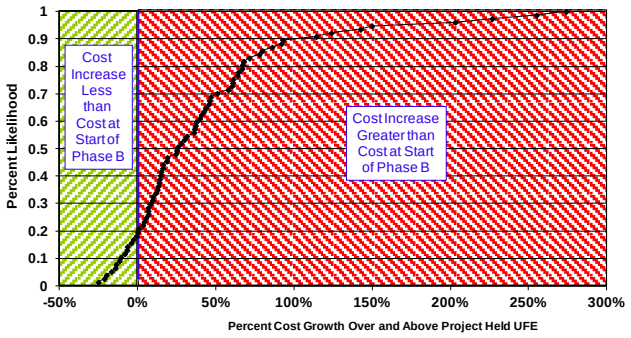
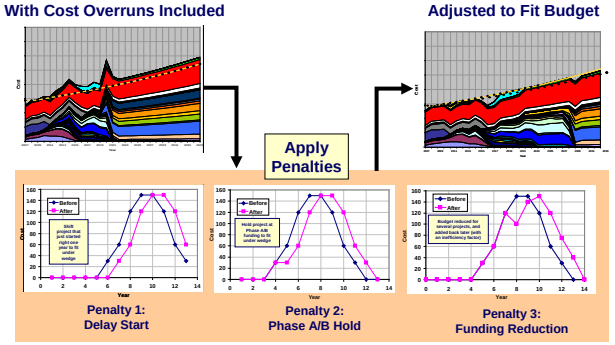
High Level Flow of Analysis

Historical Data Input



Utilize Sand Chart Tool



Run Case Matrix

Budget Confidence Level (BCL)

Funding C/L (FCL)	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%
20%	1	2	3	4	5	6	7	8	9	10	11	12	13
25%		14	15	16	17	18	19	20	21	22	23	24	25
30%			26	27	28	29	30	31	32	33	34	35	36
35%				37	38	39	40	41	42	43	44	45	46
40%					47	48	49	50	51	52	53	54	55
45%						56	57	58	59	60	61	62	63
50%							64	65	66	67	68	69	70
55%								71	72	73	74	75	76
60%									77	78	79	80	81
65%										82	83	84	85
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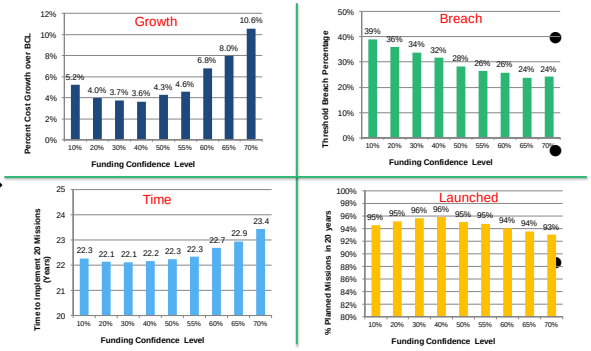
Develop Results for 3 Scenarios

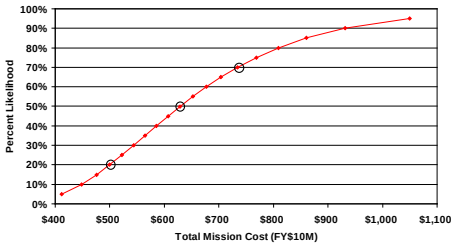


Scenario 1: Typical SMD Mixed Portfolio

Scenario 2: All Category 2 Missions

Scenario 3: Single Project Flagship

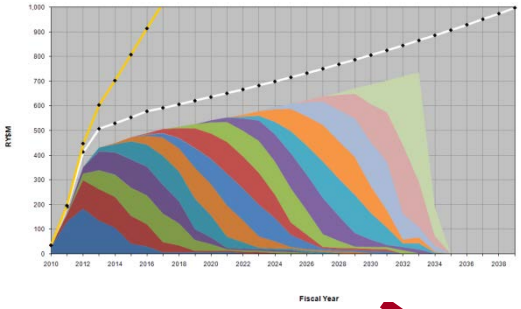
Sand Chart Tool (SCT) Provides Analytical Capability to Assess Mission Confidence Level on Portfolio Success

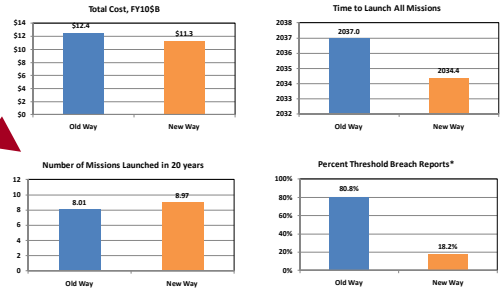


Input:
baseline plan, cost likelihood curves

- The Sand Chart Tool is a probabilistic simulation of budgets and costs
  - *Simulates a program's strategic response to internal or external events*
    - Algorithms are derived from historical data and experiences
  - *Long-term program/portfolio analysis – 10-20 years*

Perform Monte Carlo probabilistic analysis



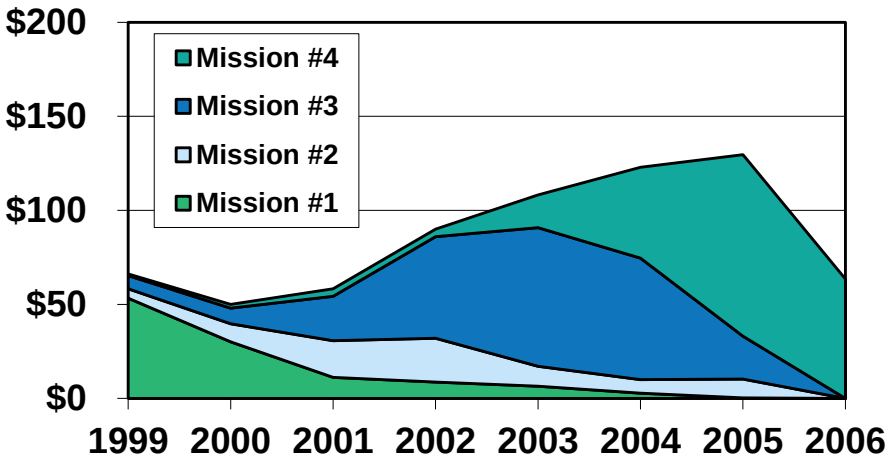


Output:
schedule likelihood curves, # of missions complete, etc.

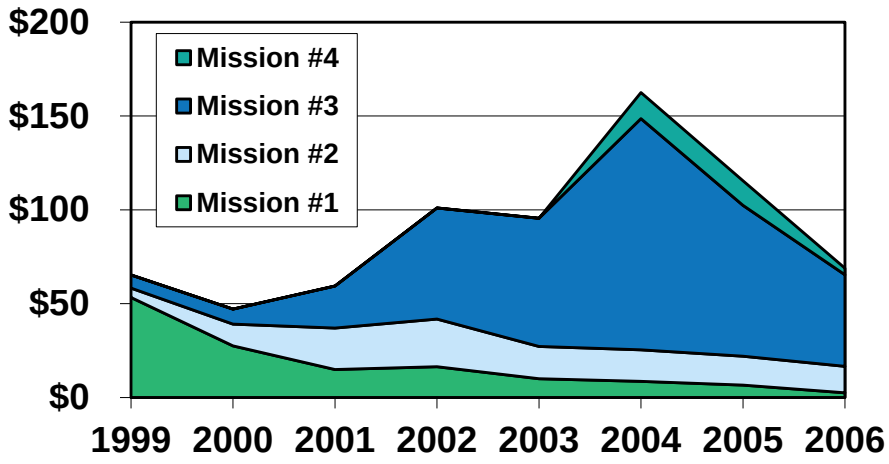
- Quantitative results to support strategic decisions
  - *Changes in mission launch dates to fit new program*
  - *Assess Figures of Merit*

Sand Chart Tool Assesses the Domino Effect for Other Projects in a Program Portfolio

Planned Funding = $690M



Actual Funding History = $715M



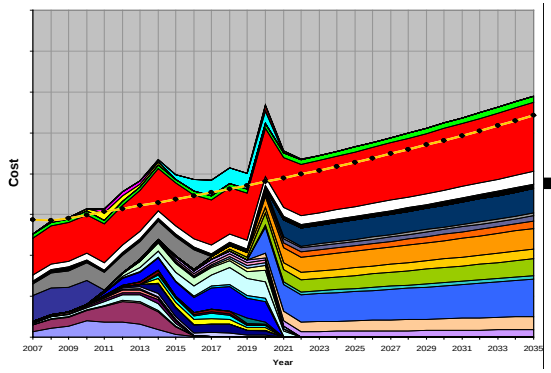
Example of actual historical program portfolio results

Although the total program funding remained consistent over this time period, implementation of successive missions were substantially affected

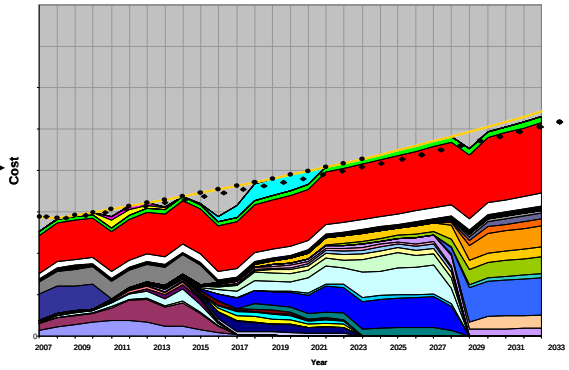
Portfolio effect adds cost due to inefficiencies of starting & delaying projects

SCT Applies Real World Penalties to Projects Based on Performance of Other Elements in Portfolio

With Cost Overruns Included

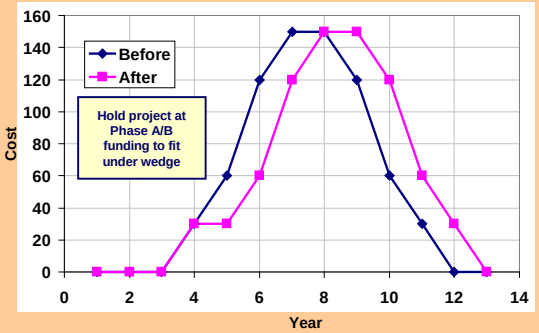


Adjusted to Fit Budget

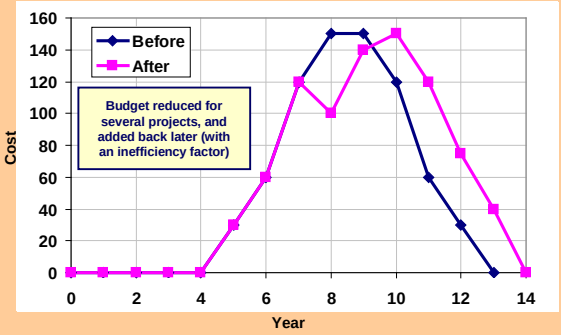


Apply Penalties

Penalty 1: Delay Start



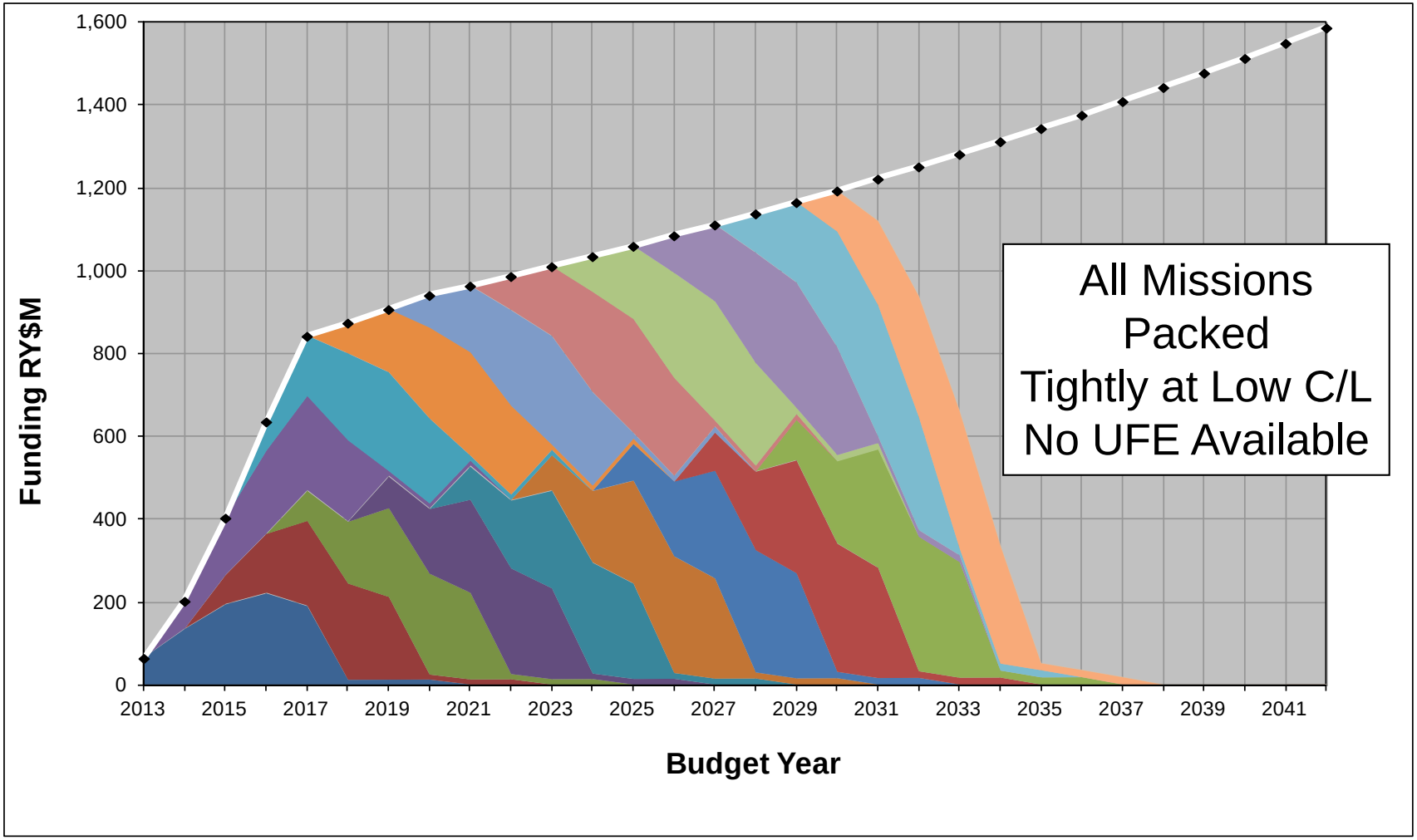
Penalty 2: Phase A/B Hold



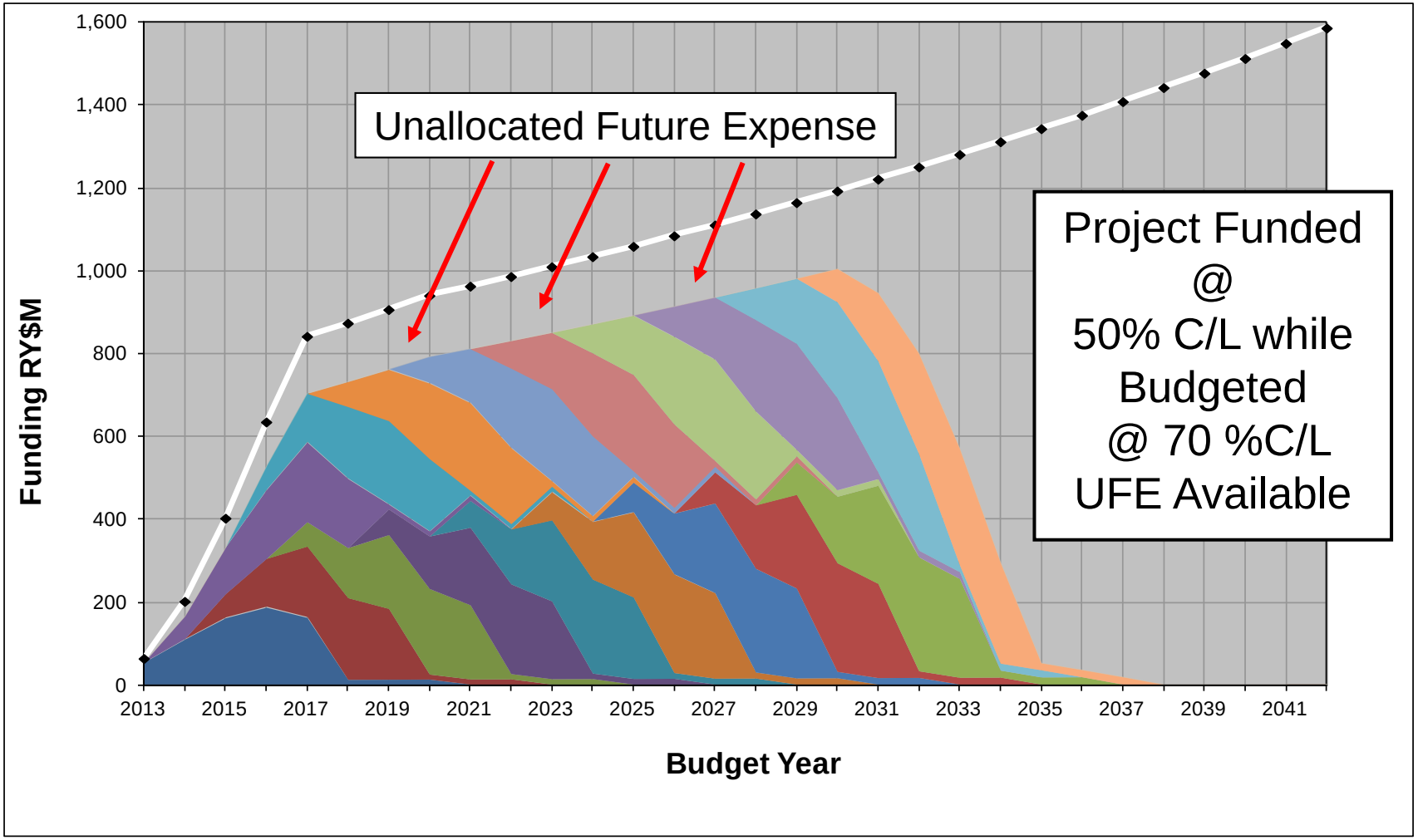
Penalty 3: Funding Reduction

Allows realistic assessment of interaction of multiple program elements or multiple missions within a given portfolio

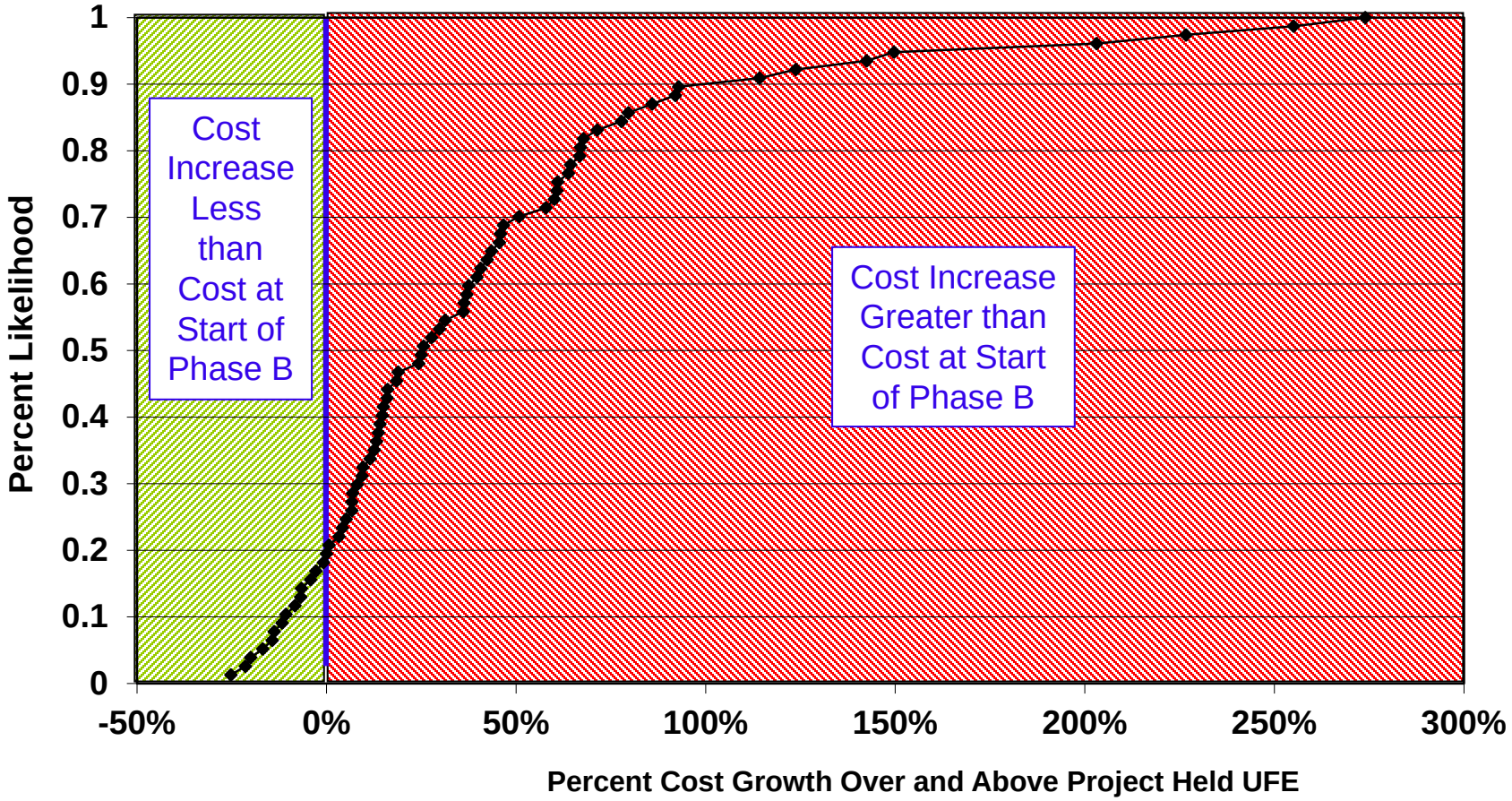
Example of "Old Way" of Budgeting



Example of New Way of Budgeting



Historical Results Used for Data Input – Missions without Launch Window Constraints



Historical average increase over 77 missions is 43%

Mission Cost Variance

- Based on historical variance – historical coefficient of variance used for all mission categories
- Broken into Category 1, 2 and 3 missions

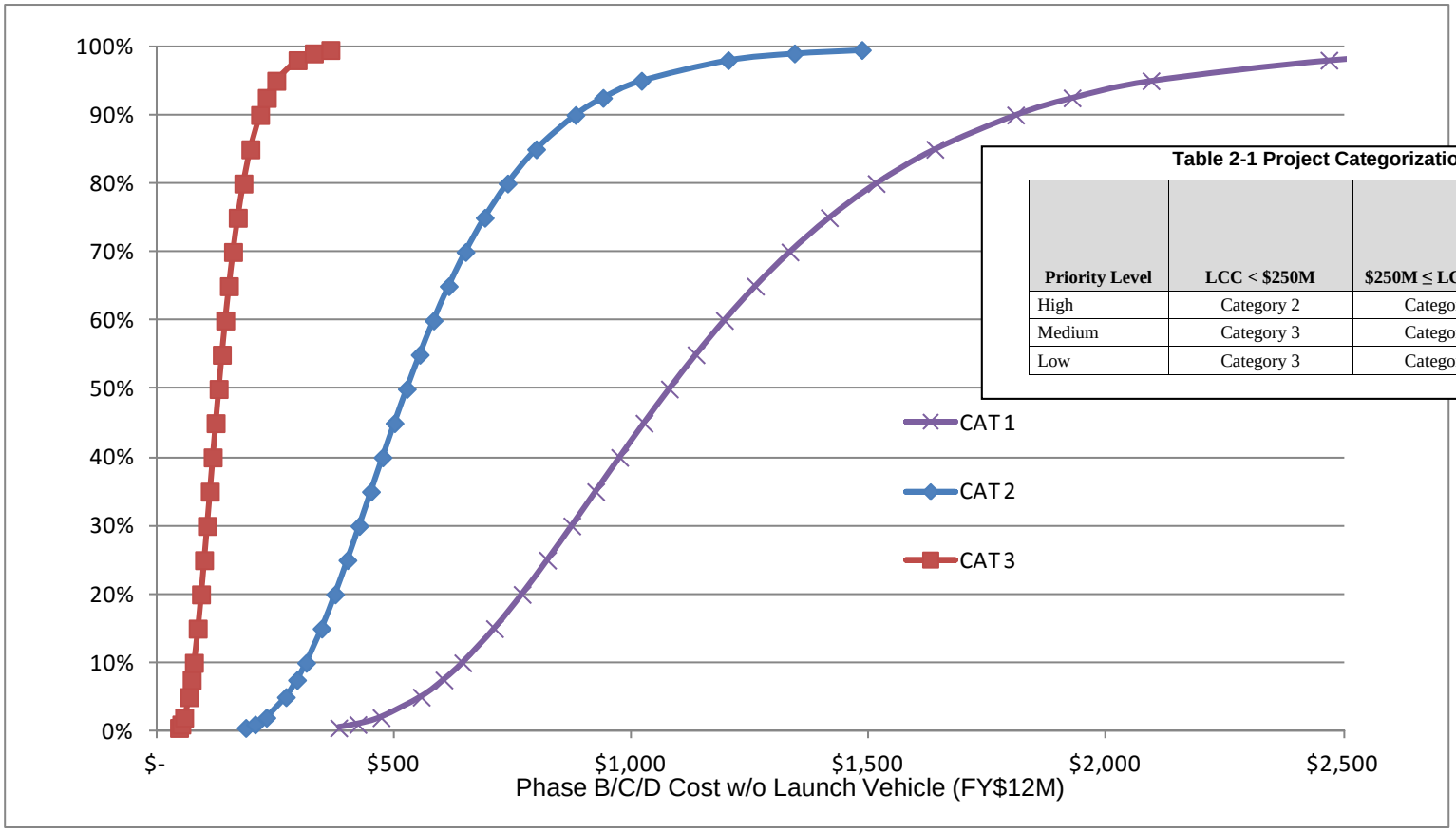


Table 2-1 Project Categorization Guidelines

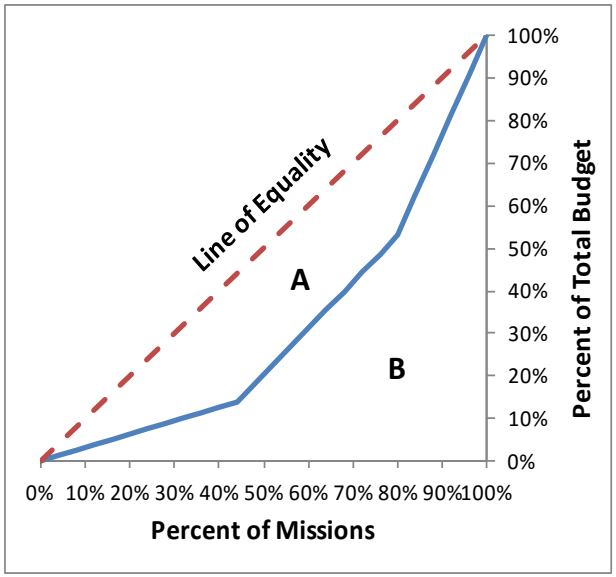
Priority Level	LCC < $250M	$250M ≤ LCC ≤ $1B	LCC > $1B, significant radioactive material, or human space flight
High	Category 2	Category 2	Category 1
Medium	Category 3	Category 2	Category 1
Low	Category 3	Category 2	Category 1

Testing the Boundaries: The Gini Coefficient

- Do all portfolios behave the same? One way to measure different "types" of portfolio is by the Gini coefficient.
- The Gini coefficient (GC) measures the inequality among values of a frequency distribution (for example levels of income)
  - *A GC of zero expresses perfect equality, where all values are the same (for example, where every project is exactly equal in programmatic posture – cost/schedule)*
  - *A GC of one expresses maximal inequality among values (for example, a single project program)*
- Research addresses three distinct portfolios
  - *Scenario 1: A representative mixed SMD portfolio (Gini coef between 0 and 1)*
  - *Scenario 2: A portfolio with all projects being equal (GC= 0)*
  - *Scenario 3: A single project program (GC = 1)*

Graphical representation of the Gini coefficient

The graph shows that the Gini coefficient is equal to the area marked *A* divided by the sum of the areas marked *A* and *B*. that is, Gini = *A* / (*A* + *B*). It is also equal to 2**A* due to fact that *A* + *B* = 0.5 (since the axes scale from 0 to 1



Source - Wikipedia

Goal is to cover the "corner solutions" of possible portfolio makeup

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SCT Study Figures of Merit (FOMs)

- Equal Content, Variable Cost
  - *Percentage cost growth over initial plan*
- Equal Content, Variable Time
  - *Time to launch first twenty missions*
- Equal Time, Variable Content
  - *Percentage of planned missions launched in a 20 year period*
- Program Volatility
  - *Percentage of time that missions exceed the 15% cost growth threshold breach requirement**

* Note: Of the 11 SMD missions under breach reporting requirements in FY08, 10 missions had experienced a breach

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Effect of Budget Confidence Level

- Looks at diagonal of case matrix where FCL = BCL
- Used to test if there is a knee in the curve for BCL

Funding C/L \ Budget C/L	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%
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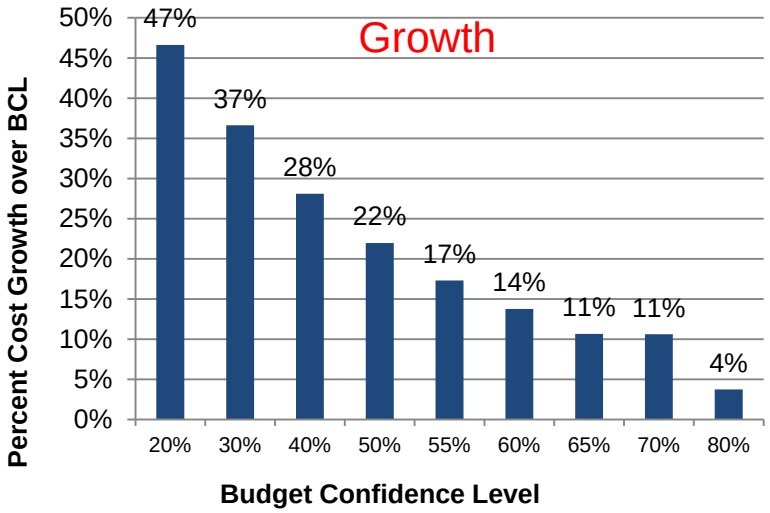
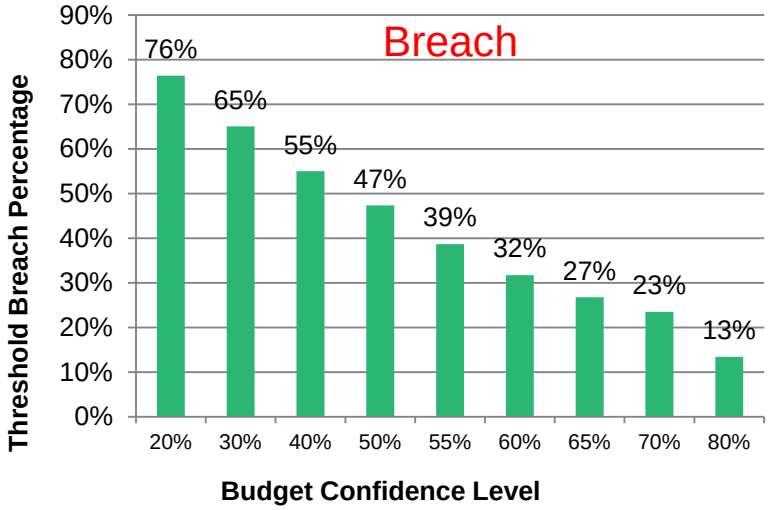
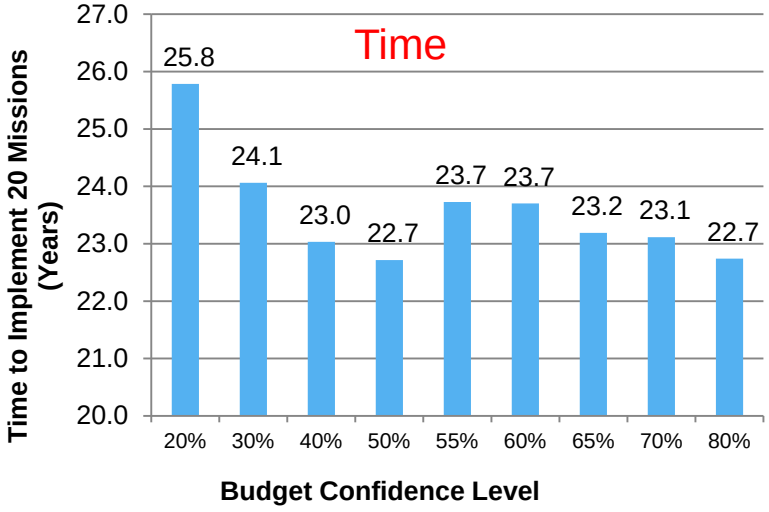
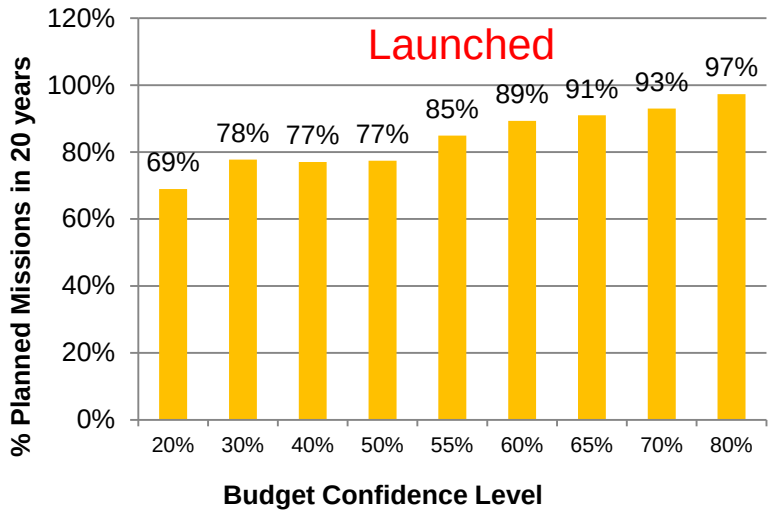
Effect of BCL – Summary



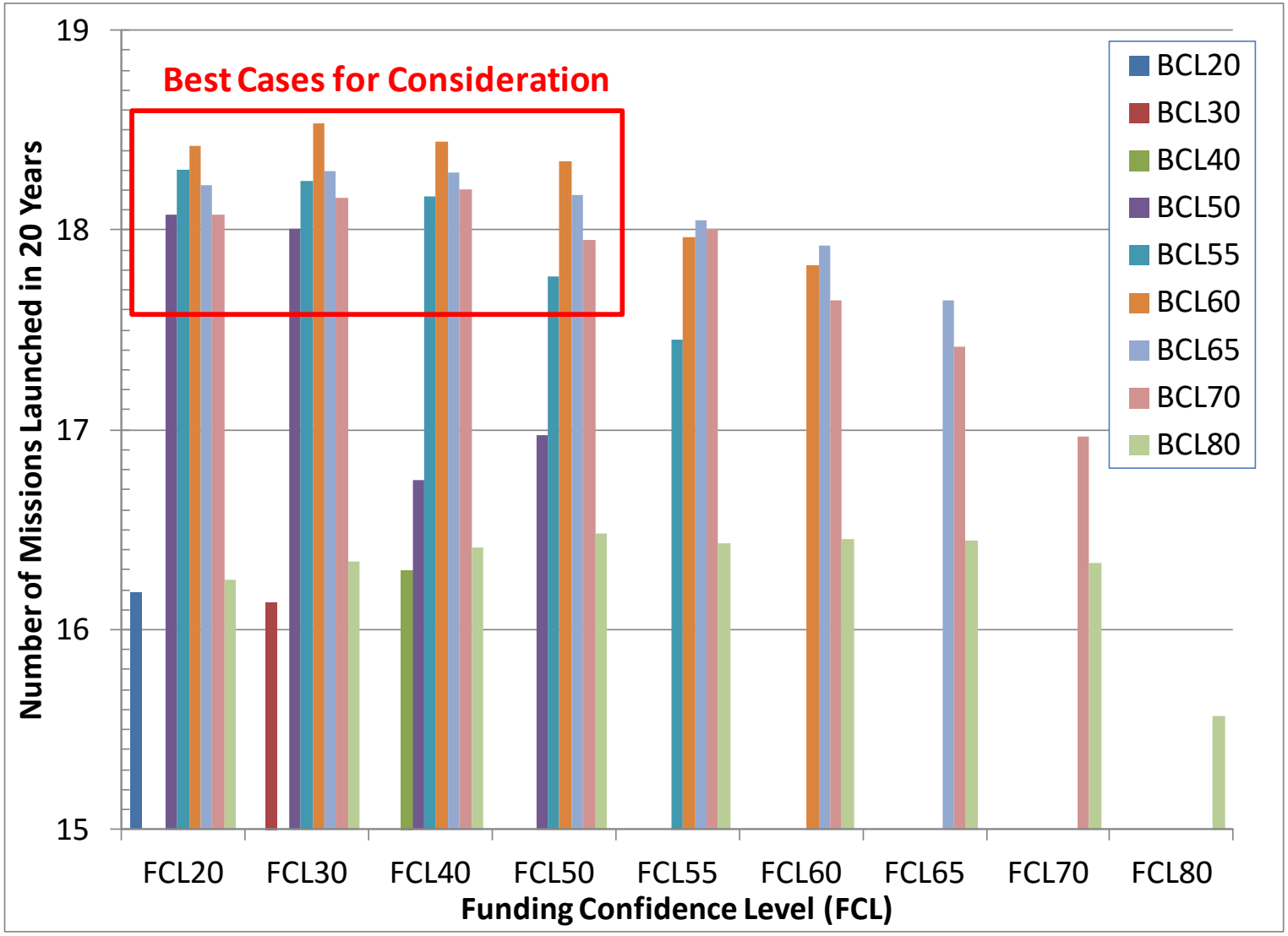






General trend is that FoM worsens as BCL decreases

Number of Missions Implemented – Scenario 1



"Best" cases are for 55% to 70% BCL and FCL 50% or less

Choice of "Best" BCL & FCL Case

- Results show that FoM performance worsens as BCL decreases
- These FoMs, however, are based on performance relative to plan
- The absolute number of missions implemented is considered, a subset of cases show maximum performance
  - *For scenario 1, "best" cases are for 55% to 70% BCL and FCL 50% or less*
- The best overall case then should be the highest BCL, since the higher BCL provides the best performance relative to plan, while providing close to the maximum number of missions implemented
  - *The best BCL case should therefore be the 70% BCL case*

Effect of Funding Confidence Level

- Looks at column of case matrix where FCL varies for a given BCL
- Used to test if there is a knee in the curve for FCL given a BCL

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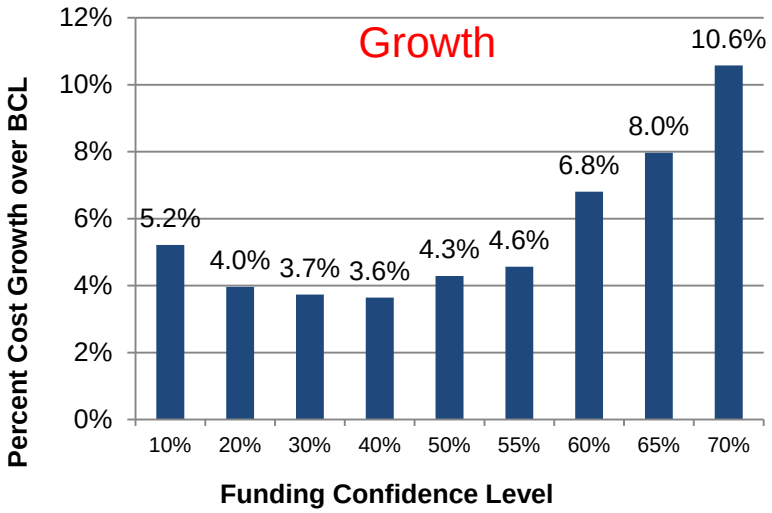
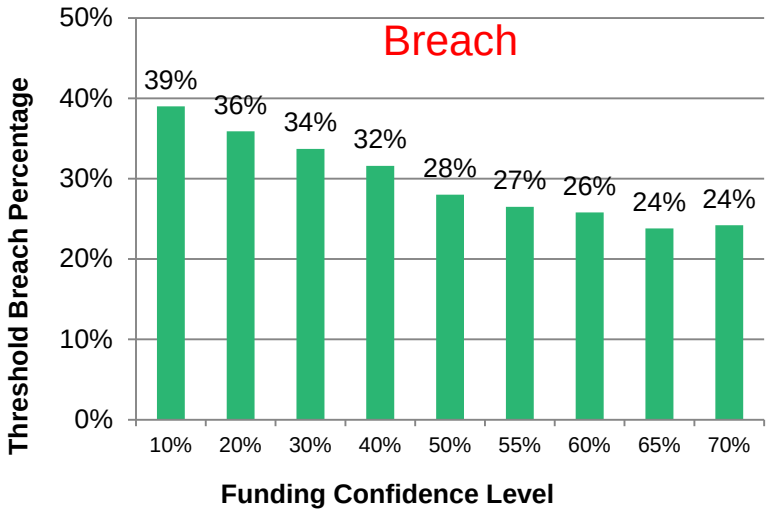
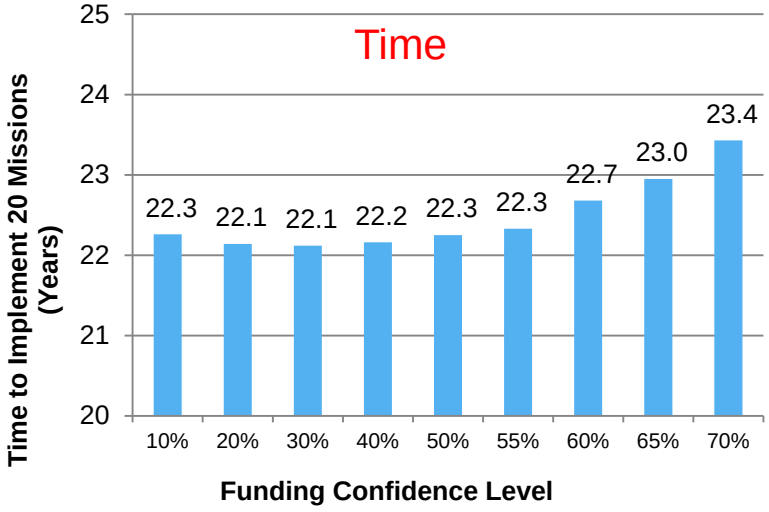
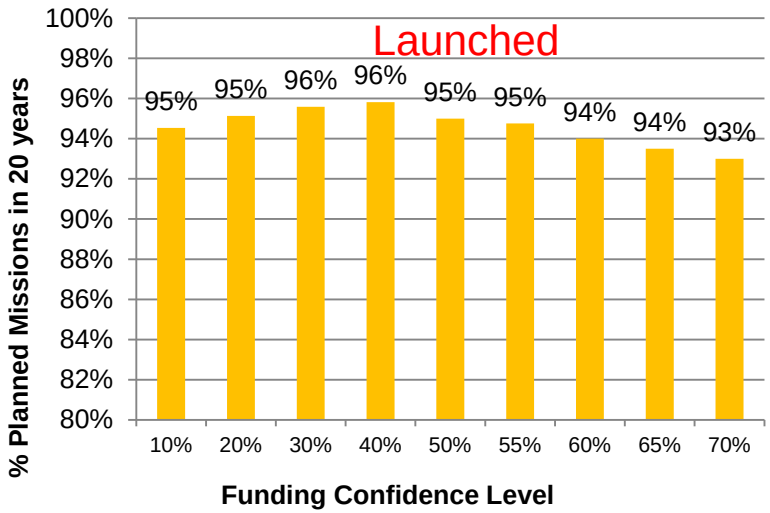
Effect of FCL @ 70% BCL – Mixed Portfolio Missions









For 70% BCL, 50% FCL looks most effective for Scenario 1

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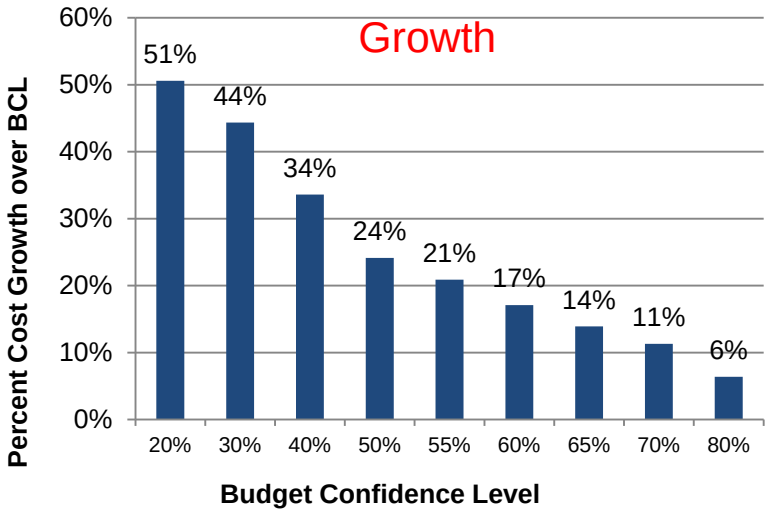
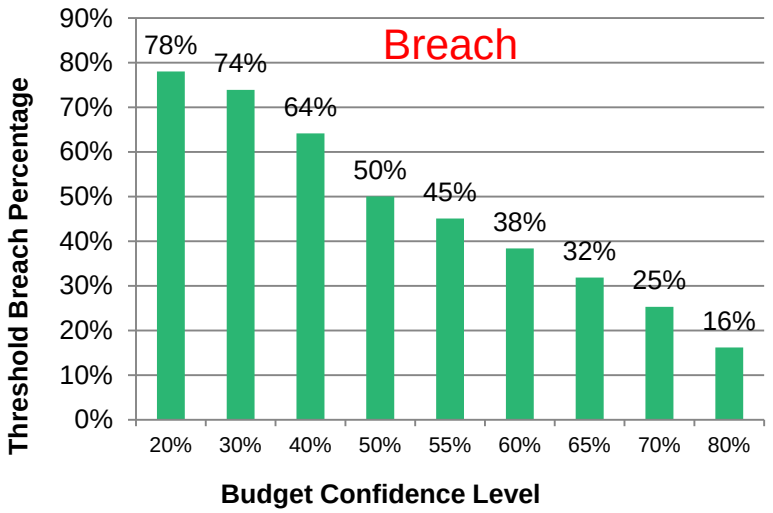
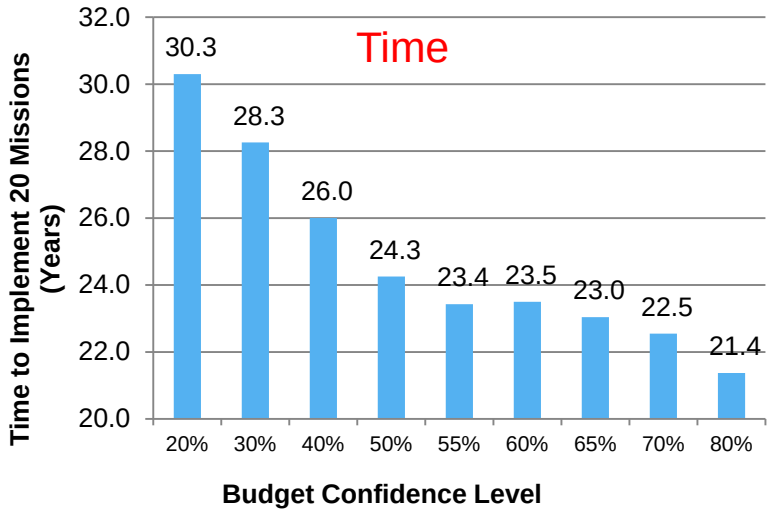
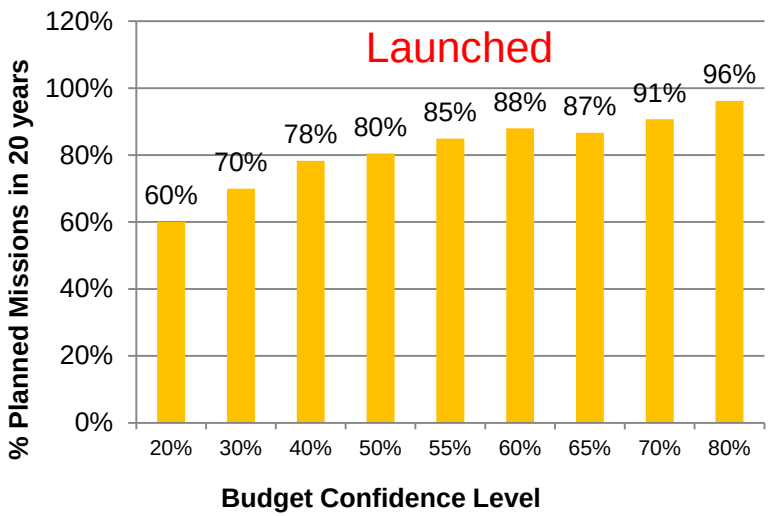
- Summary

Effect of BCL – All the Same Case Summary



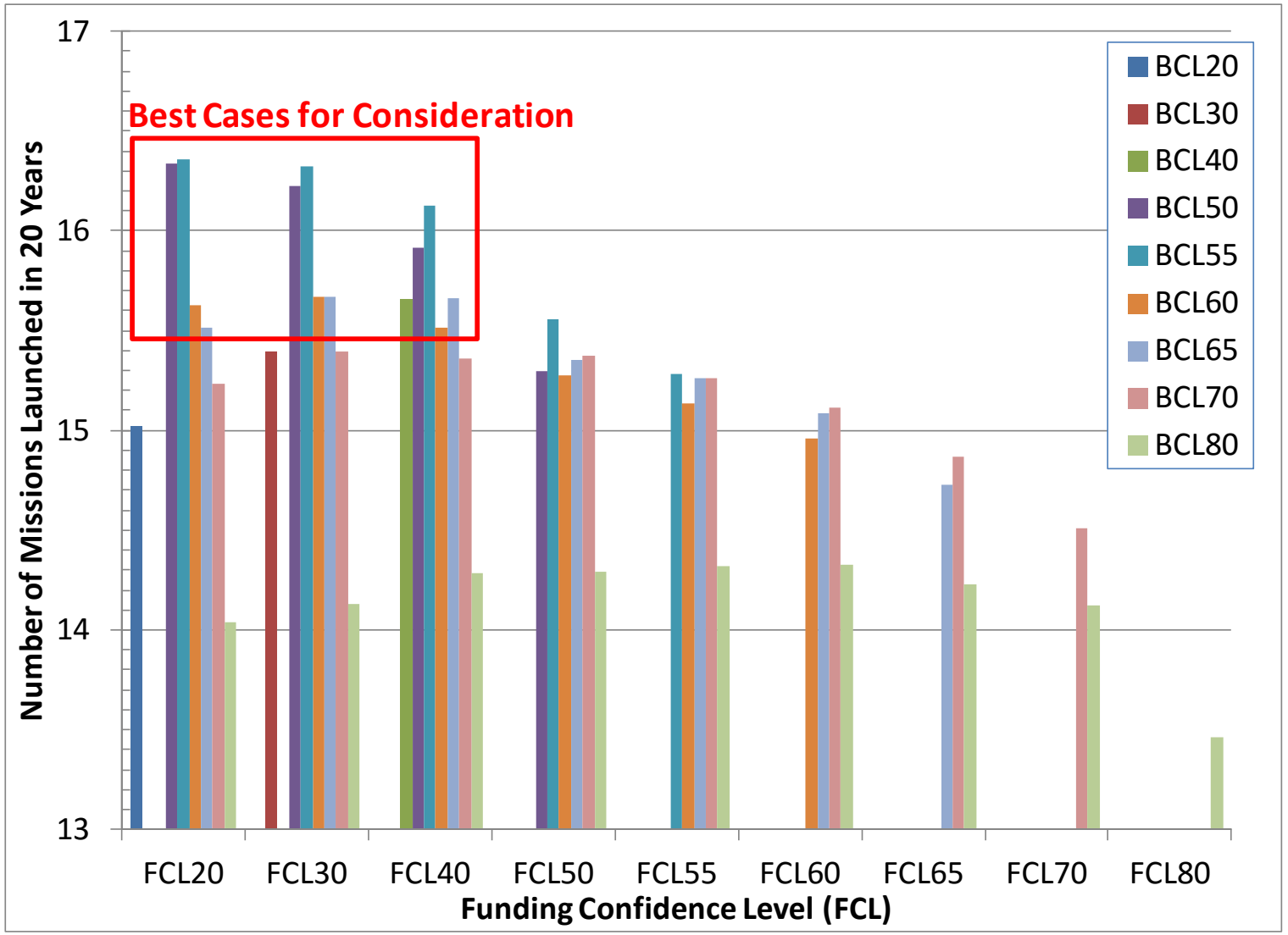






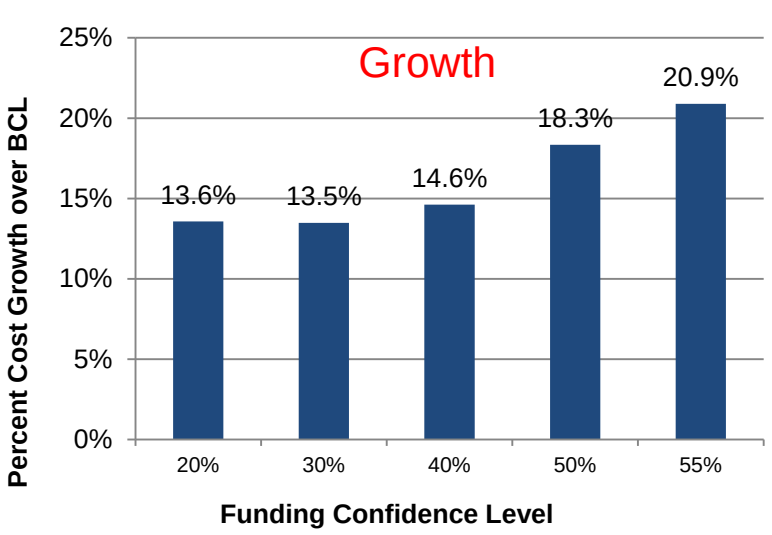
Trends are similar to Scenario 1 where FoM worsens as BCL decreases

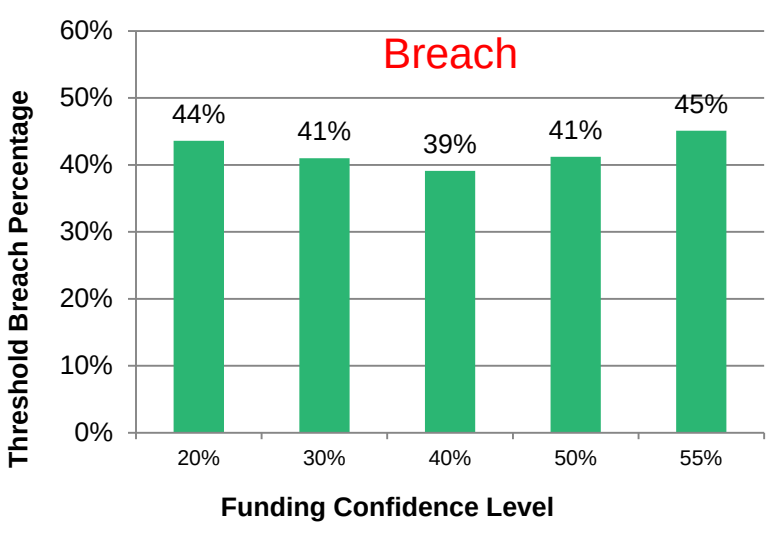
Number of Missions Implemented – Scenario 2

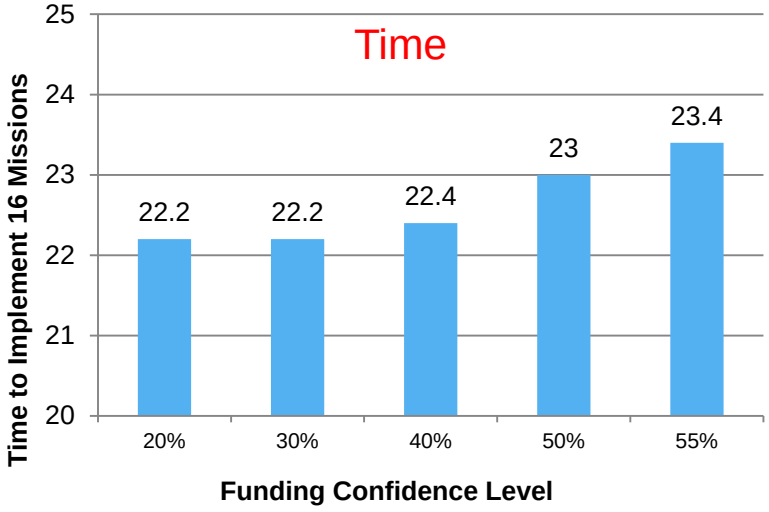


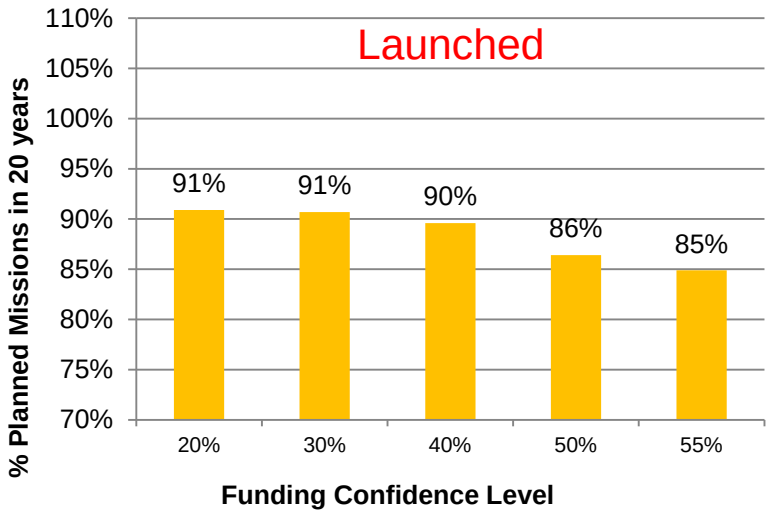
Cases of "best" number of missions implemented are smaller

Effect of FCL @ 55% BCL – All Same Category 2 Missions









For 55% BCL, 40% FCL looks best for Scenario 2

Agenda

- Background
  - *Overview*
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- Results
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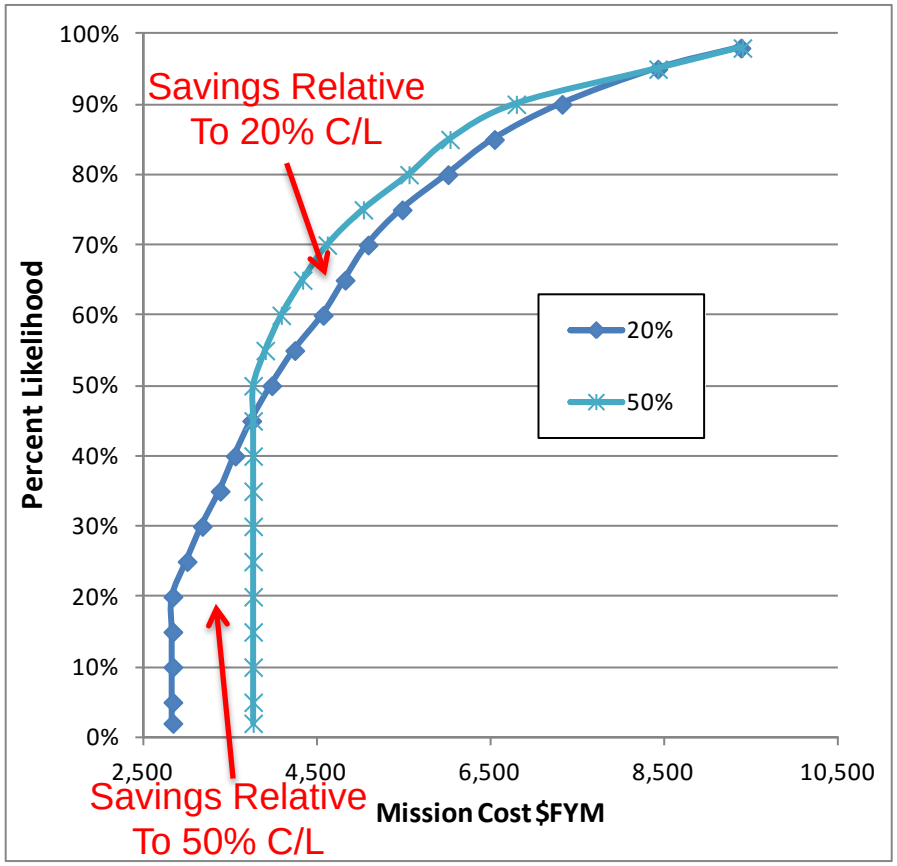
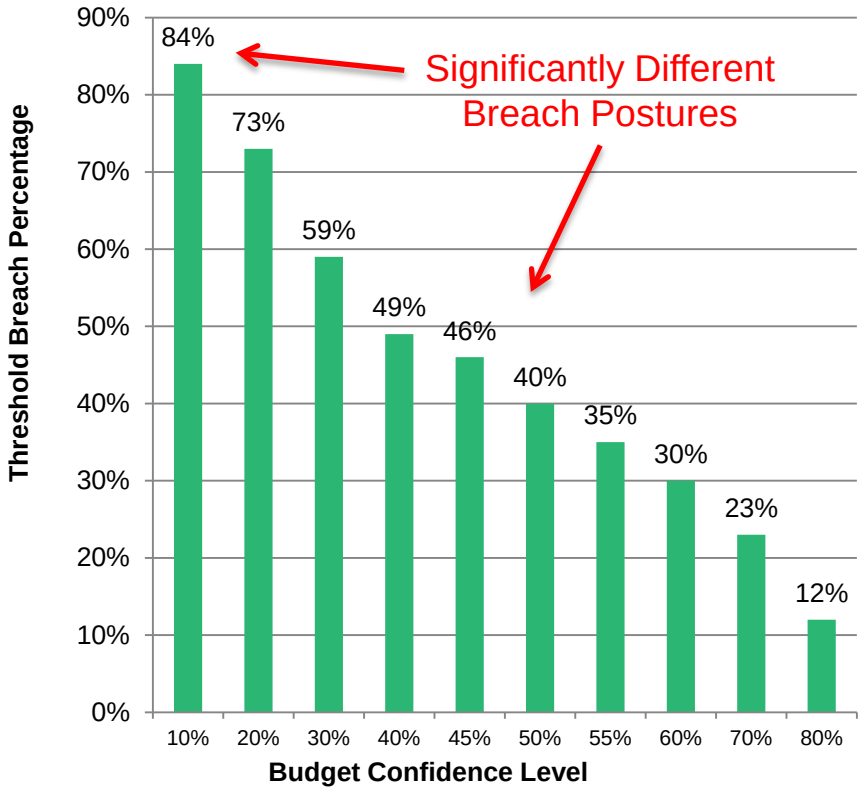
  - *Scenario 1: Typical Portfolio Mix*
  - *Scenario 2: All Projects Equal*
  - *Scenario 3: Single Project Flagship*
- Summary

Single Project Flagship Analysis

- Assumed $4B dollar mission mean LCC
  - *Includes $250M for launch and 5 years of ops at $250M total*
  - *Results in $3.5B in development cost*
  - *Cost variance based on large data of historical mission variance*
- Funding ramps up and then is capped at $400M annually
  - *First year is $150, then $300M and then $400M annually to launch*
- For Single Project Flagship FCL = BCL
  - *Since primary output looks at single mission*
- Primary difference in resulting draws is time to launch
  - *Cost draw must fit under curve so only variable in play is delay in launch date*

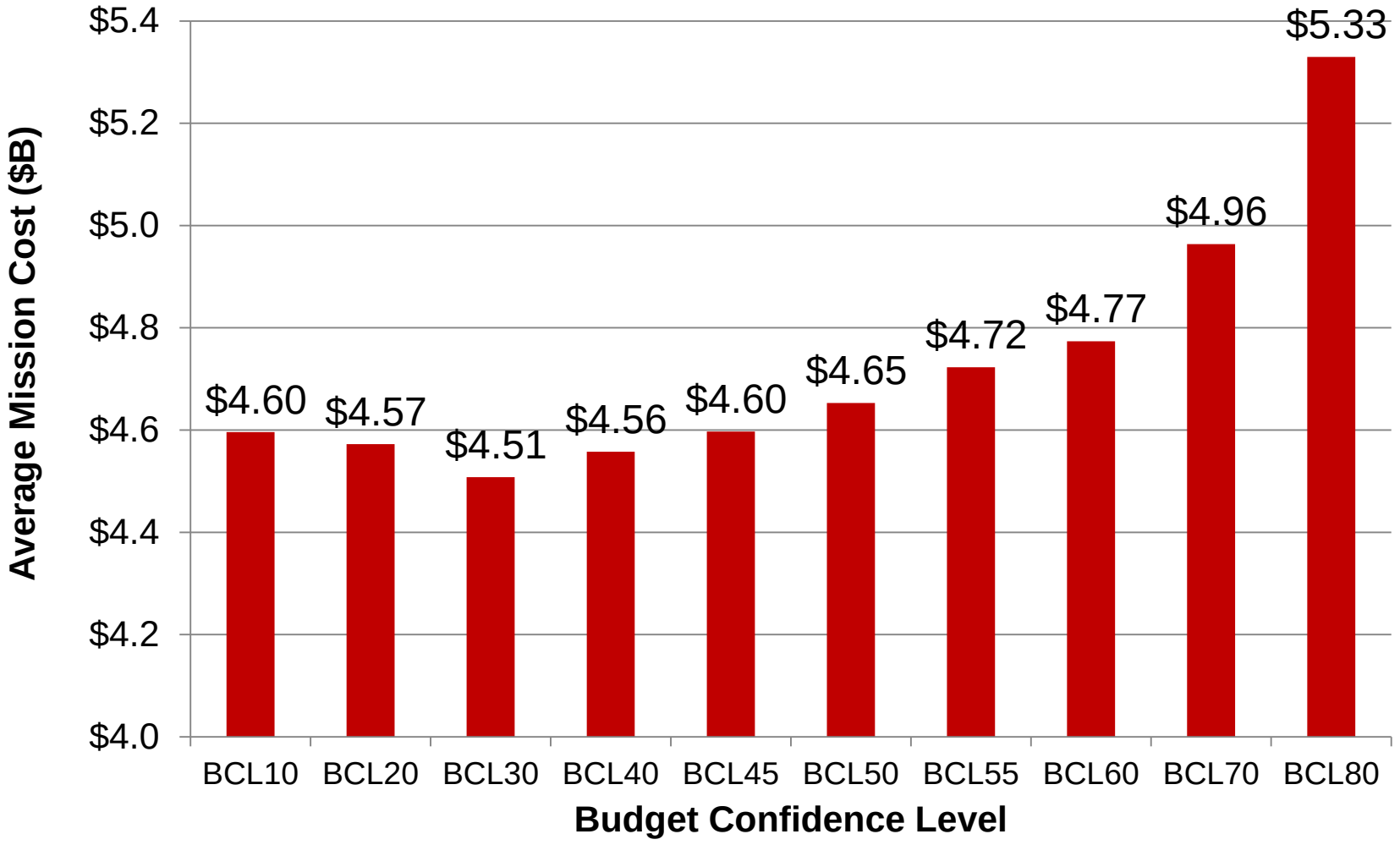
Cost S-Curve Examples – Is Potential Cost Savings Balanced by Additional Breach Reporting?





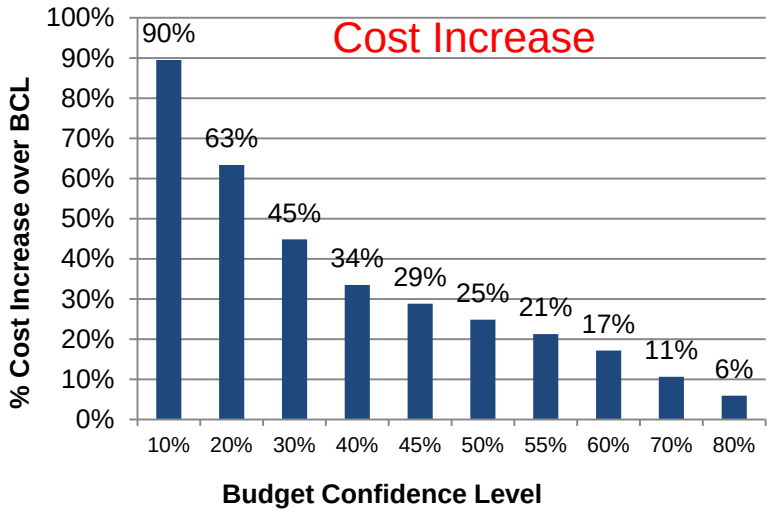
Is potential additional savings worth greater number of breaches?

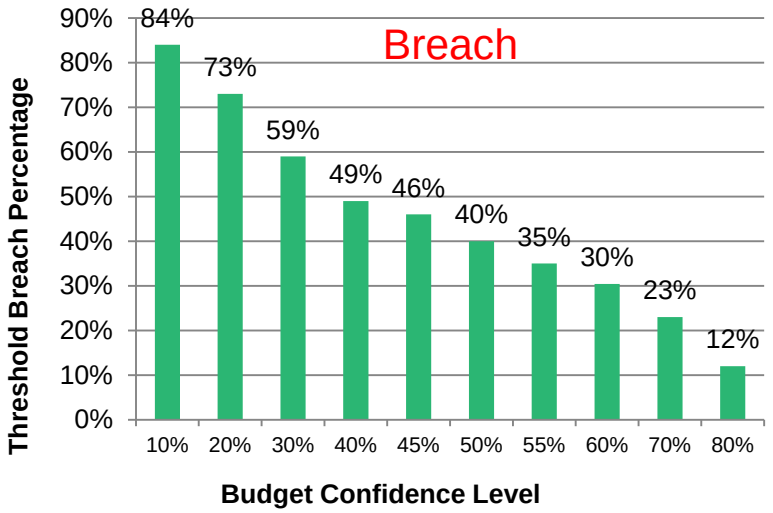
Effect of BCL – Average Mission Cost

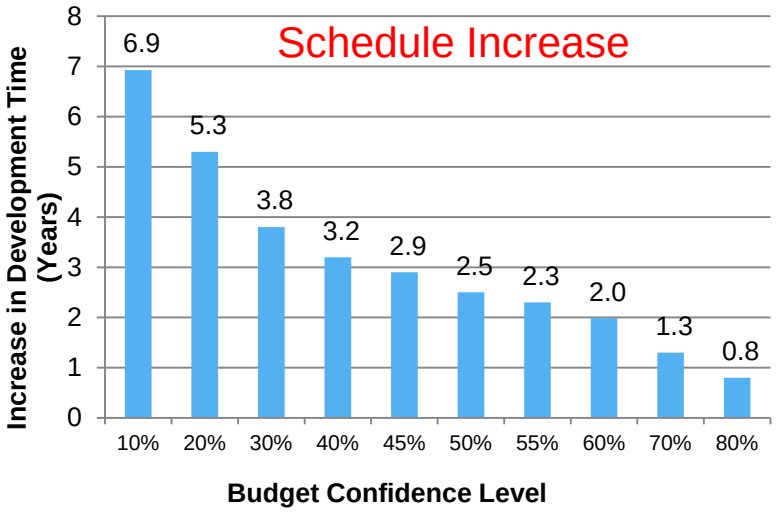


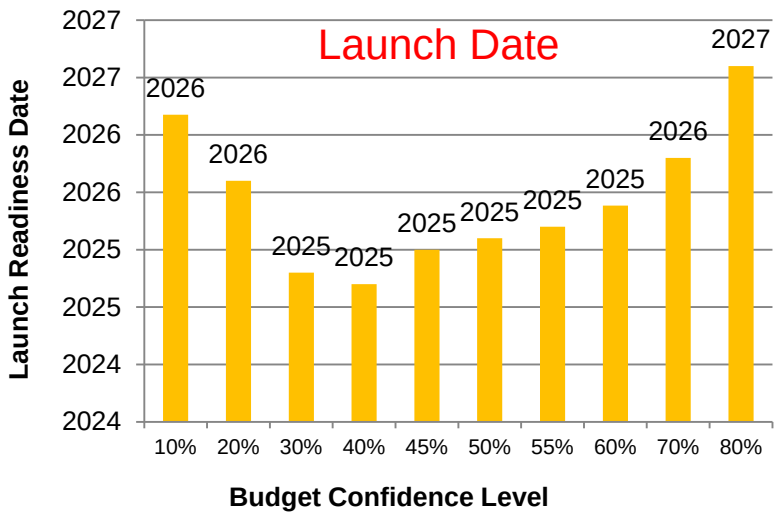
Results may make case for lower BCL for single project programs

Effect of BCL – Single Project Flagship Summary









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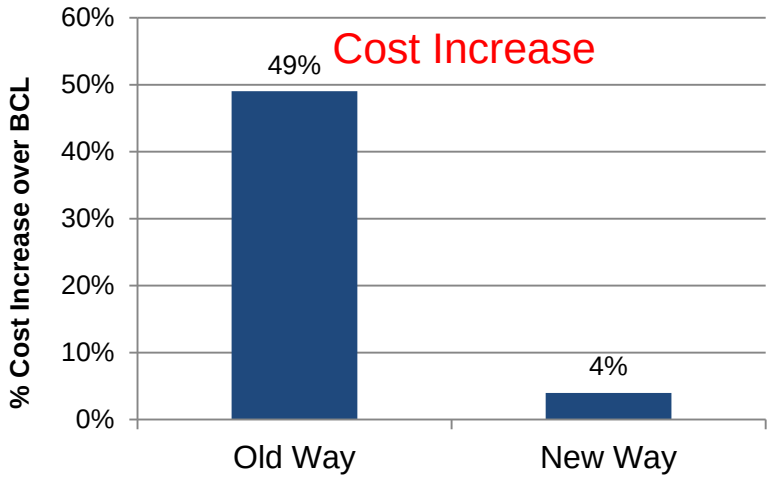
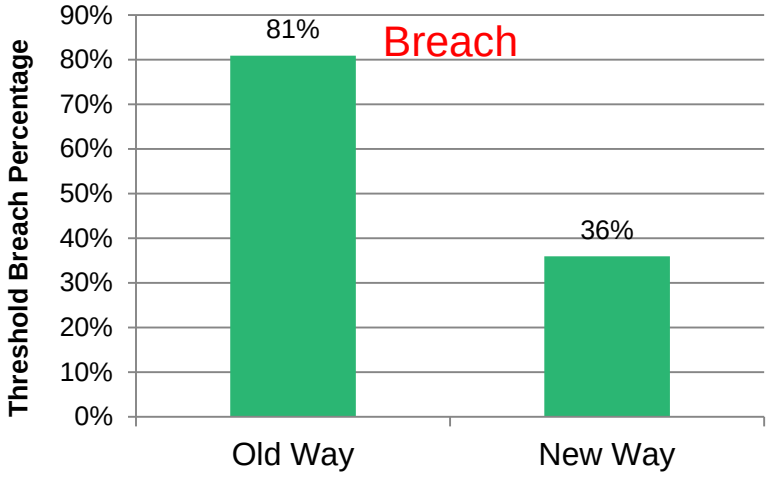
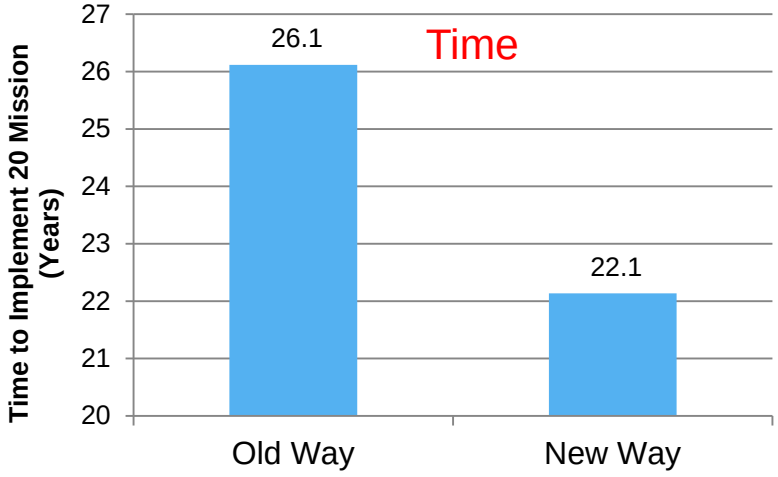
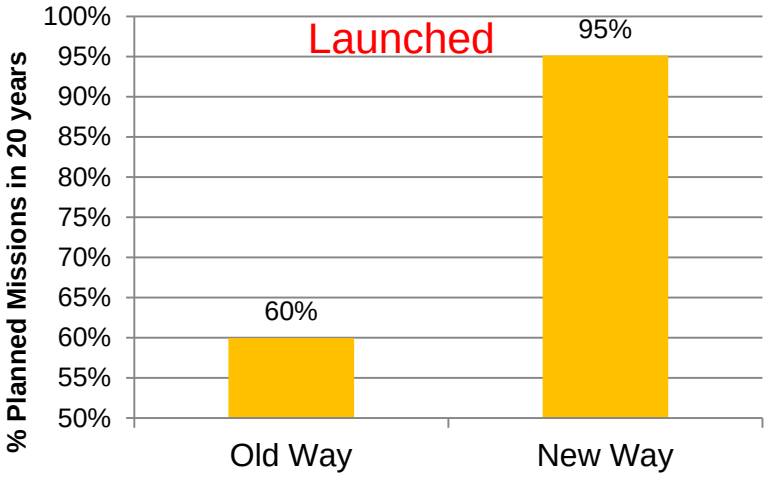
Summary – The "New Way" is Better than the "Old Way"









New Way of 70% BCL, 50% FCL is better than Old Way of 20% BCL, 20% FCL

Summary

Assessing the Impact of Confidence Levels in Funding and Budgeting NASA Science Missions

- Analysis shows that for a typical portfolio of multiple loosely coupled missions, NASA's baseline JCL policy of budgeting projects at the 70th percentile and funding to at least the 50th percentile seems to be a sound strategy

- However, for single-project Programs, NASA's baseline JCL policy may be less than an optimal strategy as data is indicates that a CL of ≤ 50th for Budgeting Confidence Level may be more cost effective depending on acceptable level of threshold breach tolerance

- Different budgeting and funding strategies could be beneficial depending on management FOM priorities and portfolio characteristics