OFFICE OF THE DIRECTOR OF NATIONAL INTELLIGENCE

Budget Execution and Margin Simulation (BEAMS)

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Presented at the ICEAA 2023 Professional Development & Training Workshop - www.iceaaonline.com/sat2023
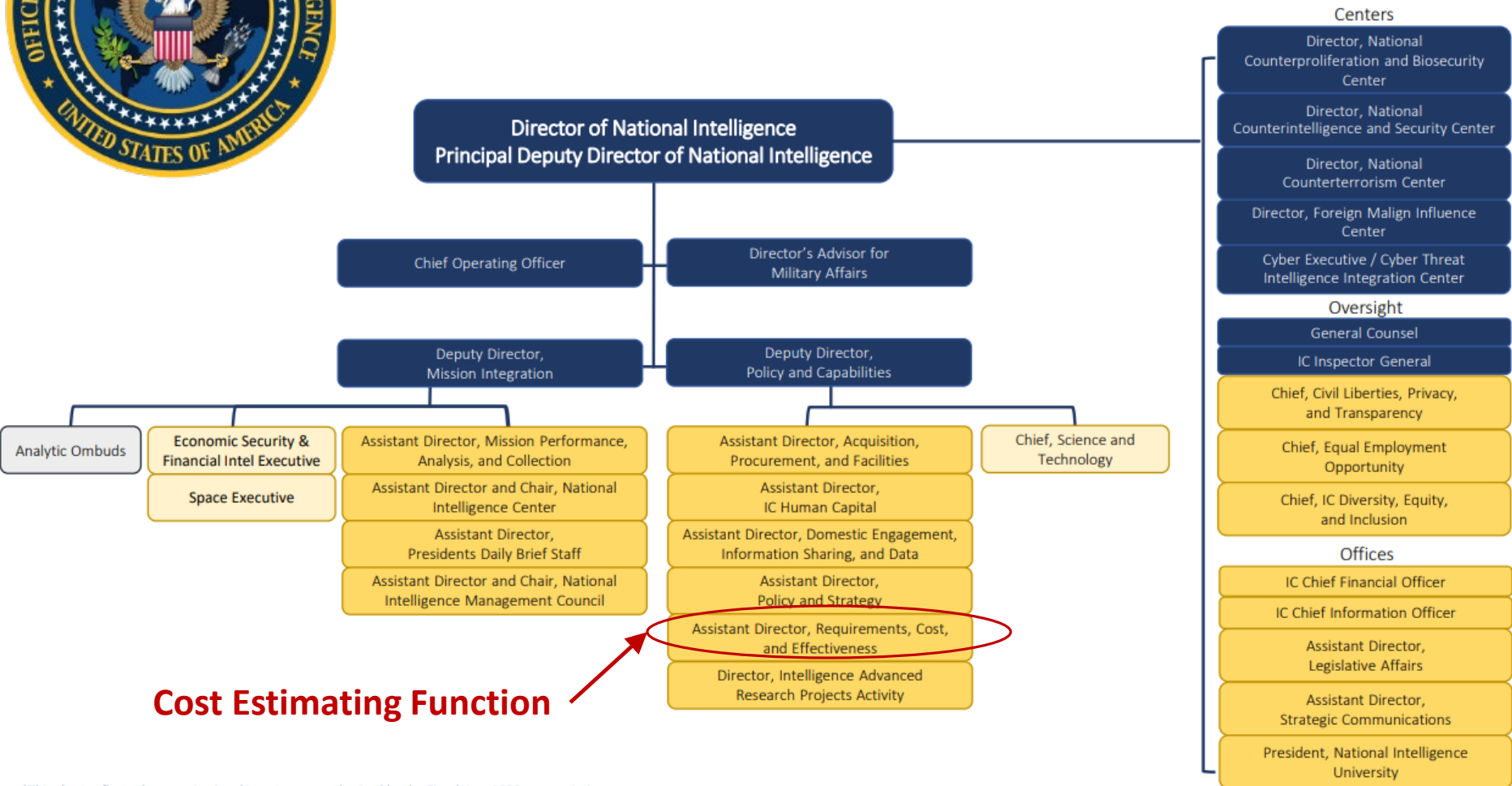
- ODNI role in Independent Cost Estimates and Portfolio Analysis

- Problem statement: Why simulate portfolio budget execution?

- BEAMS: inputs, methods, outputs

- Results: generic acquisition portfolios

- Summary

Office of the Director of National Intelligence (ODNI)

MISSION

Lead and support Intelligence Community integration; delivering insights, driving capabilities, and investing in the future

UNCLASSIFIED

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Principal Deputy Director of National Intelligence

Chief Operating Officer

Director's Advisor for Military Affairs

Deputy Director, Mission Integration

Deputy Director, Policy and Capabilities

Analytic Ombuds

Economic Security & Financial Intel Executive

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Assistant Director and Chair, National Intelligence Center

Assistant Director, Presidents Daily Brief Staff

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Assistant Director, IC Human Capital

Assistant Director, Domestic Engagement, Information Sharing, and Data

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Assistant Director, Legislative Affairs

Assistant Director, Strategic Communications

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*This chart reflects the organizational structure as authorized by the Fiscal Year 2022 appropriation.

Statutory Requirements

Independent Cost Estimates (ICEs) for individual acquisitions	Long-term Projections of Agency portfolios

ICE, Budget to ICE

[50 U.S.C. § 3097]
N.S.A. 1947 - SEC. 506A

(1) Develop ICEs for major system acquisitions (MSAs)

(2) Budget to the ICE, or explain why not

(3) Include the most current ICE in the budget justification materials submitted to Congress

FYIP, Annual Compendium

[50 U.S.C. § 3103]
SEC. 506G - Future Budget Projections

(a) Future Year Intelligence Plans (FYIP) - DNI shall provide to Congress a FYIP

(b) Long-term Budget Projections (LTBP) - DNI shall provide to Congress a LTBP (5 yrs post-FYIP) for each element of the Intelligence Community acquiring a major system

(c) Major System Affordability Report - DNI shall prepare a report for each Major System
- assess whether the Major System will cause an increase to the FYIP or LTBP
- update whenever an ICE must be updated

Congress Requires ICEs and Portfolio-Level Analyses from ODNI

FY20-22 ICES AND SPECIAL STUDIES
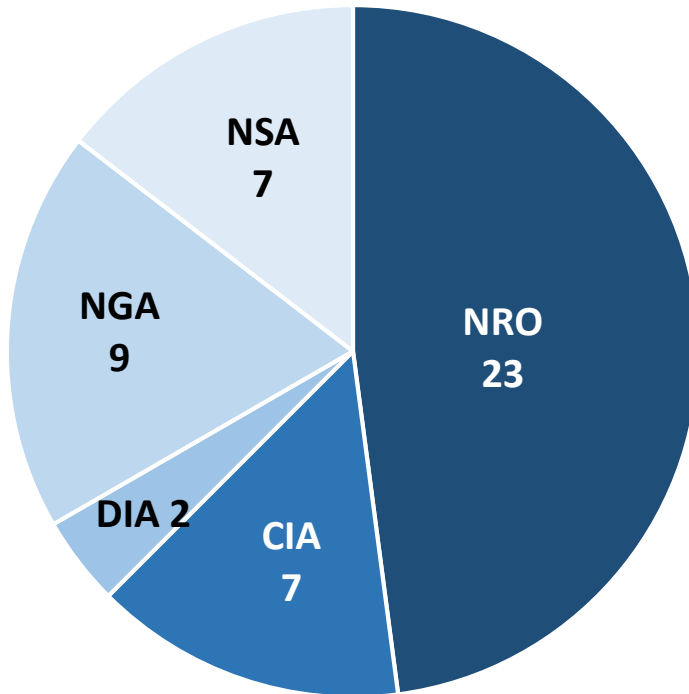
- National Reconnaissance Office (NRO) programs represent ~50% of ICEs
  - By number of ICEs … more by $$
  - Average 3.5 months to complete

- "End-to-end" impacts captured to the extent possible in related ICEs for other Agencies

- ICEs serve many functions:
  - Statutory requirement to establish program budgets and deliver ICEs to Congress for MSAs
  - Required artifact at Milestone decision reviews
  - Establish cost baselines for Program Management Plans
  - Support Analyses of Alternatives, major studies, Congressionally directed actions, OMB requests, etc.

Problem Statement

- Estimating individual acquisitions in isolation doesn't give a full picture of risk

- Recent analysis by NASA[1] takes other factors into account
  - There is interaction among programs: a "domino effect" of overruns can occur within a portfolio
  - Also, we should consider amount of mission ultimately delivered
  - Simulations support NASA policy: budget at 70% confidence level

- For NRO, established practice of budgeting to the "mean" is grounded in math[2]
  - 2003 Defense Science Board recommended space programs budget to 80%tile
  - Math shows that individual programs with uncorrelated risks budgeted at 55-65%tile results in a high confidence portfolio

- Similar analysis on NRO portfolio needed
  - 50 U.S.C. § 3097 does not require ICEs to be at the mean
  - Domino effect is more relevant with today's high-risk acquisition workload
  - What's a recipe to **maximize delivery** and **minimize growth** of the NRO portfolio?

[1]Bitten, Robert and Hunt, Charles. "Assessing the Impact of Confidence Levels in Funding and Budgeting NASA Science Missions." Presented at the 2017 ICEAA Professional Development & Training Workshop, Portland OR, June 2017.
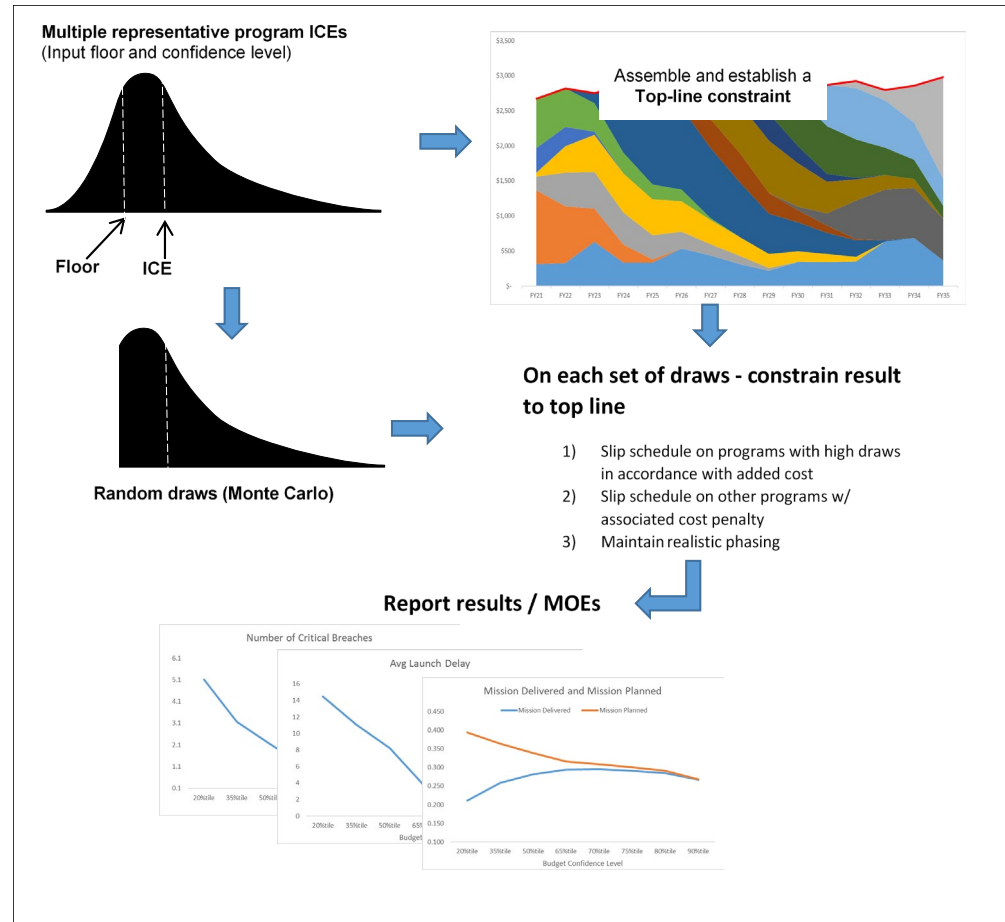[2]Anderson, Timothy. "Choosing the Appropriate Percentile for Budgeting." Aerospace Corporation white paper – January 17, 2003

BEAMS (Budget Execution and Margin Simulator)

- Stochastic simulation of cost/schedule uncertainty & budget closure
- Models the interaction among projects in NRO portfolio
- Runs with representative (not actual) programs for analysis

Similar to NASA's study

- Adapted for NRO-like portfolio and process
- Different ruleset
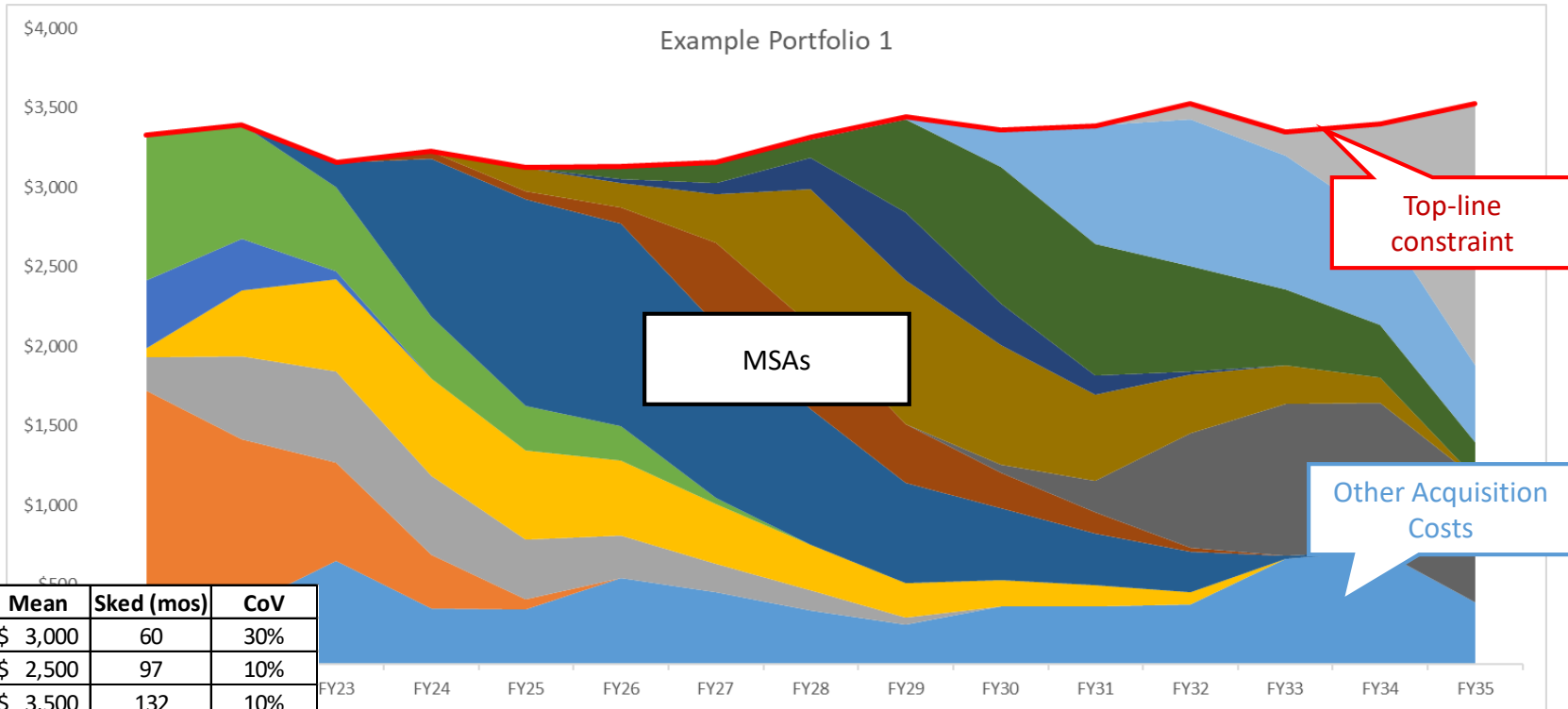- New simulation tool required

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BEAMS Process: Inputs

- Program ICE at Milestone-B (mean and standard deviation)

- Confidence percentile of ICE

- Cost "floor" (same for all programs)
  - Amount a program may come in below the MS-B budget
  - ICE and funding sometimes updated & lowered as programs mature

- Program start (defined as Milestone-B) and end dates (last launch)

- Pre-acquisition dollars

- Other acquisition costs: Portfolio costs that fall outside Major System Acquisitions
  - Includes R&D, non-MSA programs, and infrastructure
    » Fixed portion (can't be cut)
    » Variable portion (could be cut or increased)
  - Not subject to ICE

- Phasing profiles are calculated and adjusted to maintain a Weibull model with constant-rate term:[3]

    Cum cost through time t = ICE(t) = ICE*(0.25*t+1-exp(-4.25*t^1.64))/(0.25+1-exp(-4.25)),

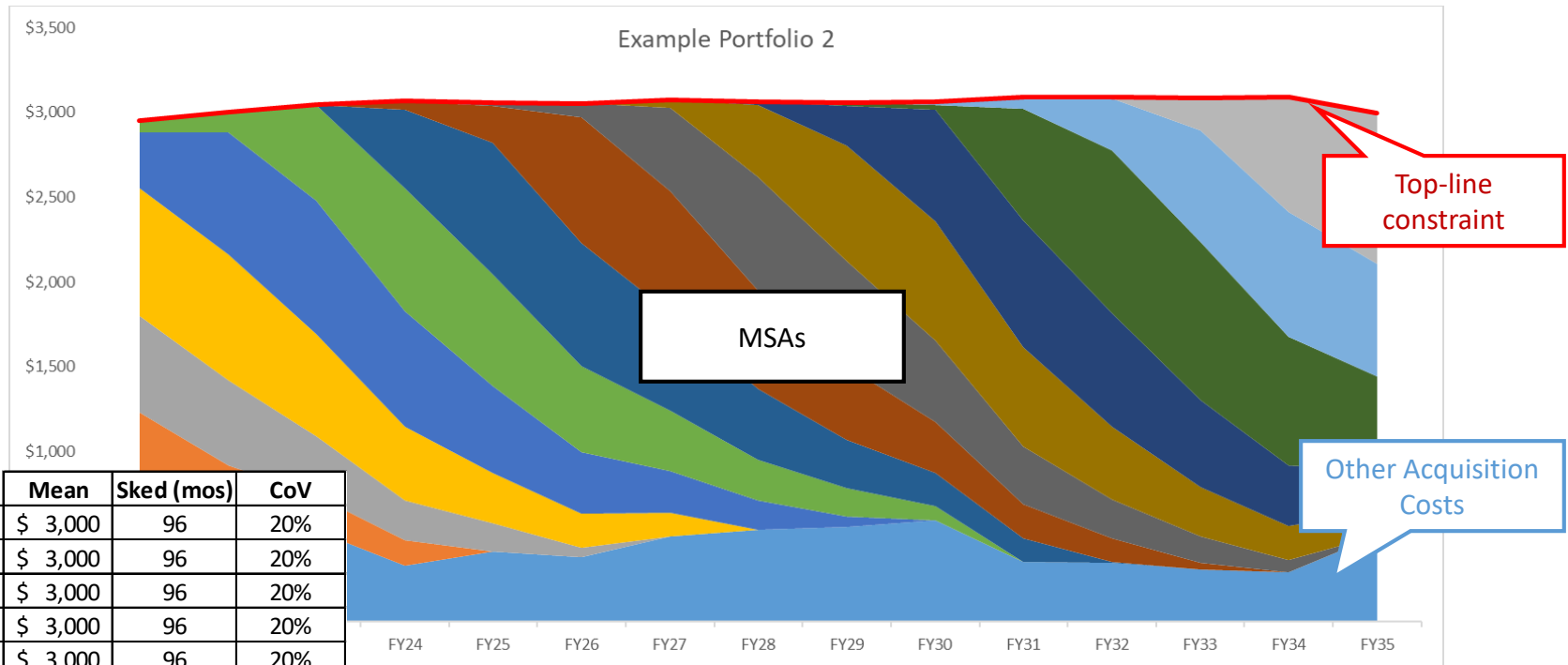   where t = 0 at program start date, t = 1.0 at end date.

[3]Burgess, Erik. "R&D Budget Profiles and Metrics." *Journal of Parametrics, Volume 25, 2006.*

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Example Portfolio: Mix of Programs

Example Portfolio 1

Top-line constraint

MSAs

Other Acquisition Costs

	Mean	Sked (mos)	CoV
Spysat A	$ 3,000	60	30%
Spysat B	$ 2,500	97	10%
Spysat C	$ 3,500	132	10%
Spysat D	$ 7,500	115	20%
Spysat E	$ 4,500	115	30%
Spysat F	$ 6,500	113	10%
Spysat G	$ 1,500	68	25%
Spysat H	$ 3,850	110	30%
Spysat I	$ 3,500	91	20%
Spysat J	$ 1,000	47	10%
Spysat K	$ 3,500	96	20%
Spysat L	$ 3,500	100	25%
Spysat M	$ 5,000	79	30%

Mix of MSA types: cost, schedule, and risk

Example Portfolio: Same-Size Programs

Example Portfolio 2

MSAs

Top-line constraint

Other Acquisition Costs

	Mean	Sked (mos)	CoV
Spysat A	$ 3,000	96	20%
Spysat B	$ 3,000	96	20%
Spysat C	$ 3,000	96	20%
Spysat D	$ 3,000	96	20%
Spysat E	$ 3,000	96	20%
Spysat F	$ 3,000	96	20%
Spysat G	$ 3,000	96	20%
Spysat H	$ 3,000	96	20%
Spysat I	$ 3,000	96	20%
Spysat J	$ 3,000	96	20%
Spysat K	$ 3,500	96	20%
Spysat L	$ 3,000	96	20%
Spysat M	$ 3,000	96	20%

BEAMS Process: Simulation

- Draw (Monto Carlo) and correlate from truncated lognormal distributions of program cost, C.

- Time-phase and sum all programs by year

- Depending on random cost draw, adjust schedule as governed via bivariate cost/schedule distribution[4]

$$\Delta sked = \frac{\sigma_s}{\sigma_c} \rho_{sc}(C - ICE\$)$$

- Close to the top line using the following rules (in this order, for each year in the analysis period):
  - Cut non-MSA costs down to minimum (user-input) level
  - Slip launches: Start with high-dollar programs and iterate
  - Delay Milestone-B for new starts
  - Move pre-acquisition money around
  - Cancel a program post Milestone-B
    - » This should be rare, but it does happen
    - » Programs with lowest % completion are top targets for cancellation, and prior money stays in as "sunk"

- Record portfolio Measures of Effectiveness and Risk

- Repeat with new Monte Carlo draw (250 draws used)

Monte Carlo Draws
from Truncated Lognormal
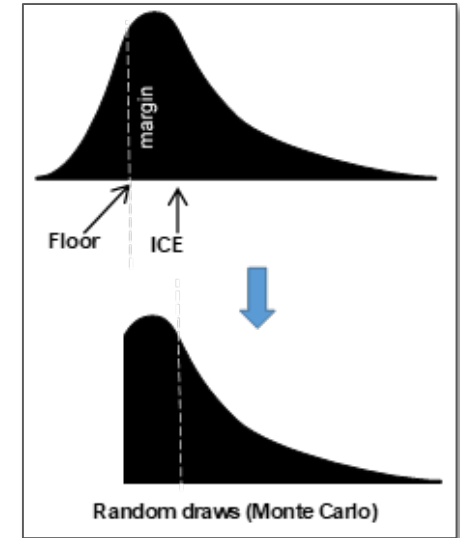
[4]Parameters of underlying normal distributions. For lognormal transformations see Garvey, Paul R. "A family of Joint Probability Models for Cost and Schedule Uncertainties." 27th Annual DoD Cost Analysis Symposium, September 1993.

- Measures of Risk:
  - Number of 15% threshold breaches (Includes programs that breached then were cancelled)
  - Number of 25% threshold breaches (Includes programs that breached then were cancelled)
  - Average program budget growth (Includes cancelled programs)
  - Average launch delay (Includes programs stretched then cancelled)
  - % of top-line budget spent on cancelled programs

- Measure of Effectiveness: Missions delivered per year, per $B
  - Faster completions (FOCs), lower costs = more capability delivered
  - Cancelled programs don't deliver anything

Assumptions for Modeling

- Threshold breaches are relative to the MS-B ICE, regardless of confidence level

- All costs are in BY$M
  - Using TY$M would give the same results
  - Escalation in program dollars = escalation in top line constraint

- Slip/stretch in program schedule = launch delay
  - Maximum of 4 years
  - Applies to single launch or multiple launch programs
  - Launch costs are not addressed discretely

- Incremental funding

Results: Low-Risk Portfolio

All 13 programs same size and duration, σ =20%, 15 year analysis window
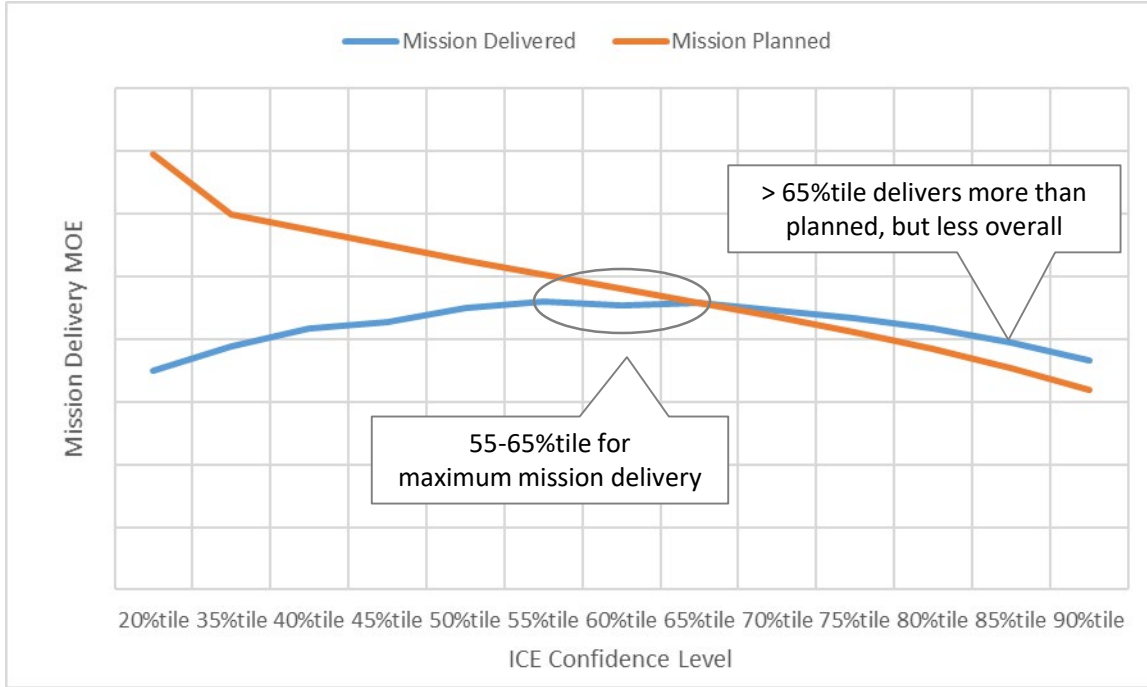
ICEs at 55-65% confidence deliver the most mission

Higher end of this range has less mission planned, but reduces breaches, delays, cancellations

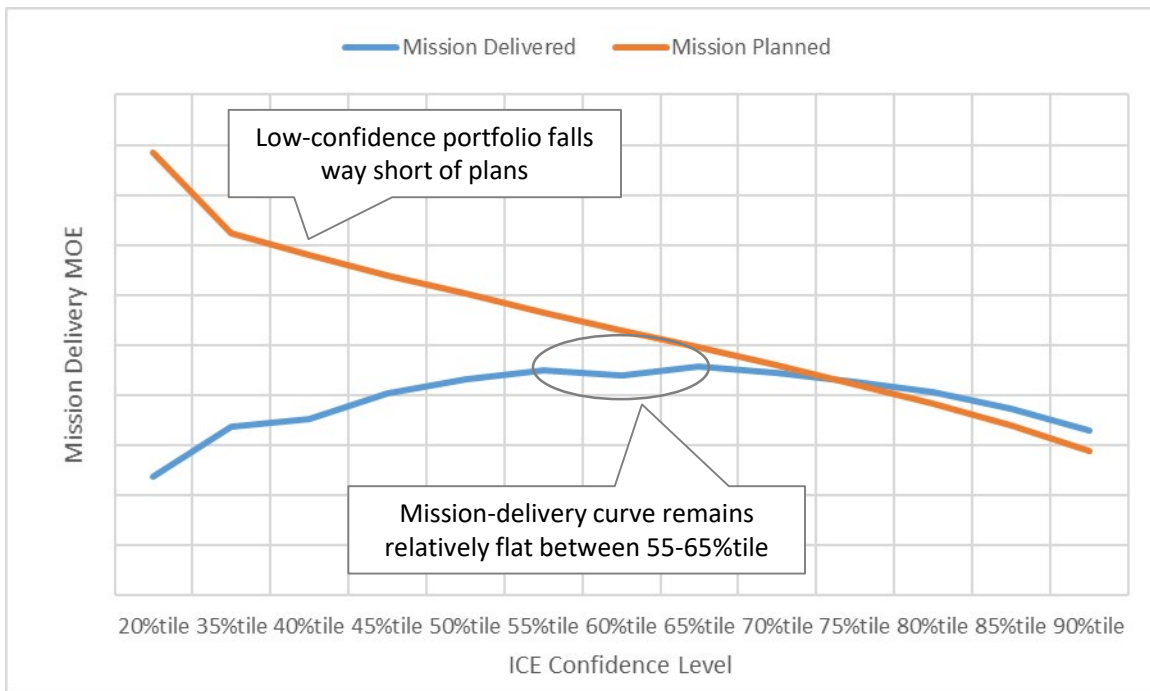## Risk Metrics All Improve with Higher Estimates, As Expected

Measures of Risk

	ICE Confidence Level												
Metric	20%tile	35%tile	40%tile	45%tile	50%tile	55%tile	60%tile	65%tile	70%tile	75%tile	80%tile	85%tile	90%tile
Number of 15% threshold breaches	7.5	5.1	4.5	3.7	3.1	2.5	2.2	1.6	1.4	1.1	0.7	0.5	0.2
Number of 25% threshold breaches	5.4	3.3	2.8	2.2	1.8	1.4	1.2	0.8	0.7	0.4	0.3	0.2	0.1
Average program growth vs. ICE	23%	13%	9%	6%	3%	0%	-2%	-5%	-7%	-10%	-13%	-16%	-20%
Average launch delay (months)	21	16	11	9	6	4	2	0	-1	-3	-4	-5	-6
Spent on Cancelled Programs	4.0%	2.8%	2.3%	1.9%	1.4%	1.0%	0.6%	0.4%	0.1%	0.1%	0.0%	0.0%	0.0%

All 13 programs same size and duration, σ =30%, 15 year analysis window

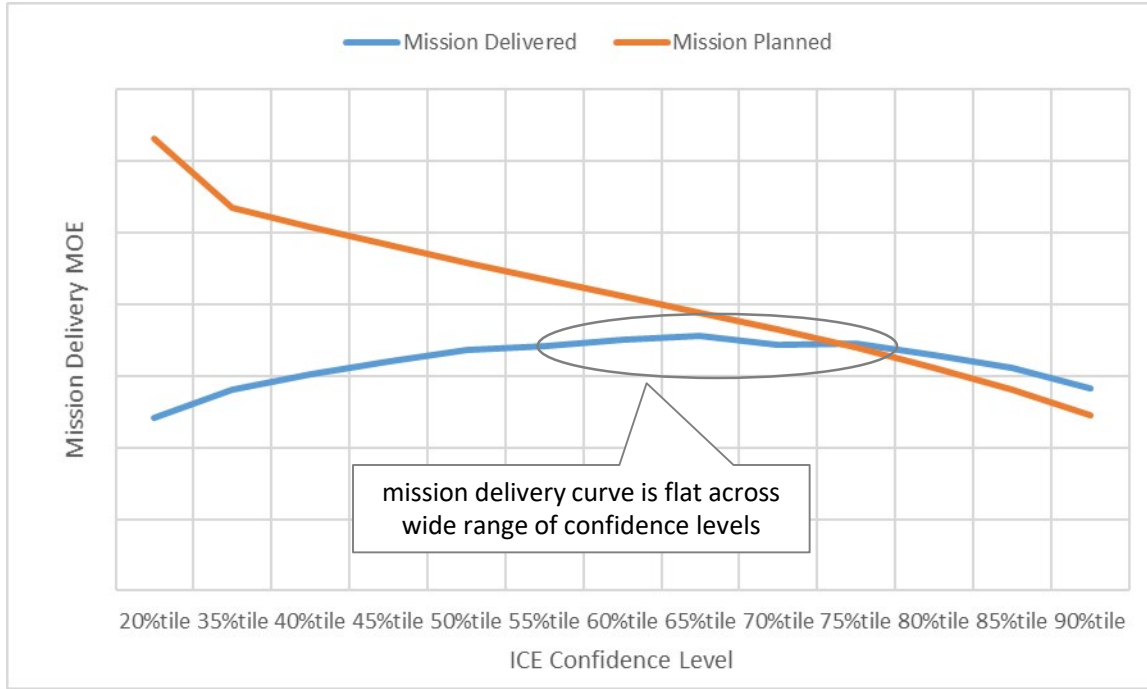Aggressive (low confidence) estimates even more risky, even less mission delivered

Mission-delivery curve similar to low-risk portfolio

Measures of Risk

Metric	ICE Confidence Level												
	20%tile	35%tile	40%tile	45%tile	50%tile	55%tile	60%tile	65%tile	70%tile	75%tile	80%tile	85%tile	90%tile
Number of 15% threshold breaches	8.6	6.6	5.9	5.0	4.2	3.6	3.0	2.4	2.0	1.6	1.1	0.8	0.4
Number of 25% threshold breaches	7.2	5.2	4.6	3.7	3.1	2.6	2.1	1.6	1.3	1.0	0.6	0.4	0.2
Average program growth vs. ICE	39%	24%	19%	12%	8%	3%	0%	-5%	-8%	-12%	-17%	-21%	-26%
Average launch delay (months)	28	29	24	18	14	11	10	3	2	-1	-2	-4	-5
Spent on Cancelled Programs	8.7%	4.9%	4.5%	3.3%	2.7%	1.6%	1.3%	0.8%	0.4%	0.4%	0.1%	0.0%	0.0%

Results: Mixed Portfolio w/Overall Medium Risk

13 programs, overall σ =23%, 15 year analysis window

— Mission Delivered   — Mission Planned

mission delivery curve is flat across wide range of confidence levels

Mission Delivery MOE — ICE Confidence Level

20%tile 35%tile 40%tile 45%tile 50%tile 55%tile 60%tile 65%tile 70%tile 75%tile 80%tile 85%tile 90%tile

Portfolio is a realistic mix with several low-risk, follow-on type programs

Flat mission-delivery curve over wide range

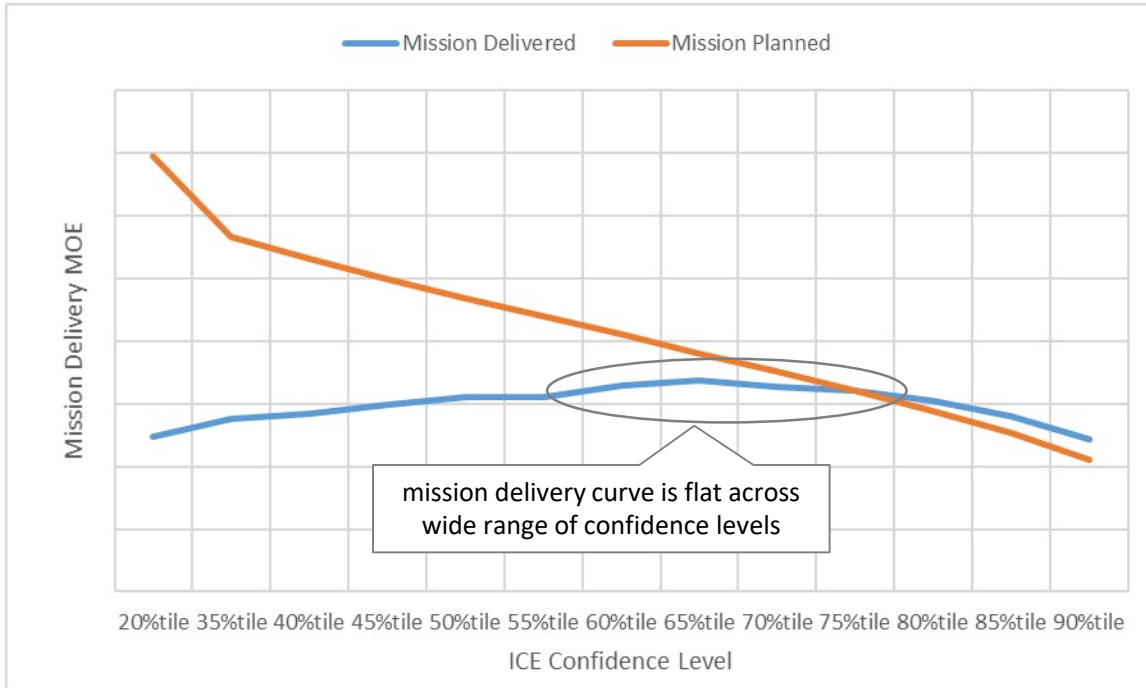|	Mean	Sked (mos)	CoV
Spysat A	$ 3,000	96	15%
Spysat B	$ 6,000	108	30%
Spysat C	$ 2,100	90	30%
Spysat D	$ 1,200	96	10%
Spysat E	$ 3,500	84	30%
Spysat F	$ 3,000	119	10%
Spysat G	$ 4,500	83	30%
Spysat H	$ 3,000	84	10%
Spysat I	$ 3,850	91	15%
Spysat J	$ 800	96	35%
Spysat K	$ 3,000	96	30%
Spysat L	$ 8,500	144	20%
Spysat M	$ 2,500	95	30%

Measures of Risk

Metric	ICE Confidence Level												
	20%tile	35%tile	40%tile	45%tile	50%tile	55%tile	60%tile	65%tile	70%tile	75%tile	80%tile	85%tile	90%tile
Number of 15% threshold breaches	7.5	5.3	4.6	4.0	3.3	2.7	2.3	1.7	1.4	1.2	0.8	0.6	0.3
Number of 25% threshold breaches	5.7	3.7	3.1	2.6	2.1	1.7	1.5	1.0	0.8	0.6	0.4	0.3	0.2
Average program growth vs. ICE	31%	17%	13%	9%	6%	2%	0%	-4%	-7%	-9%	-13%	-16%	-20%
Average launch delay (months)	37	27	22	19	15	11	9	4	3	0	-2	-4	-5
Spent on Cancelled Programs	5.1%	2.7%	2.7%	1.9%	1.6%	1.1%	1.0%	0.6%	0.5%	0.3%	0.1%	0.1%	0.0%

Results: Mixed Portfolio w/Overall High Risk

13 programs, overall σ =28%, 15 year analysis window

— Mission Delivered — Mission Planned

Mission Delivery MOE

mission delivery curve is flat across wide range of confidence levels

20%tile 35%tile 40%tile 45%tile 50%tile 55%tile 60%tile 65%tile 70%tile 75%tile 80%tile 85%tile 90%tile

ICE Confidence Level

Portfolio is a realistic mix with mostly high-risk, new-development programs

Slightly higher confidence ICEs deliver more mission

	Mean	Sked (mos)	CoV
Spysat A	$ 3,000	96	20%
Spysat B	$ 6,000	108	30%
Spysat C	$ 2,100	90	35%
Spysat D	$ 1,200	96	25%
Spysat E	$ 3,500	84	30%
Spysat F	$ 3,000	119	20%
Spysat G	$ 4,500	83	30%
Spysat H	$ 3,000	84	30%
Spysat I	$ 3,850	91	25%
Spysat J	$ 800	96	35%
Spysat K	$ 3,000	96	30%
Spysat L	$ 8,500	144	30%
Spysat M	$ 2,500	95	20%

Measures of Risk

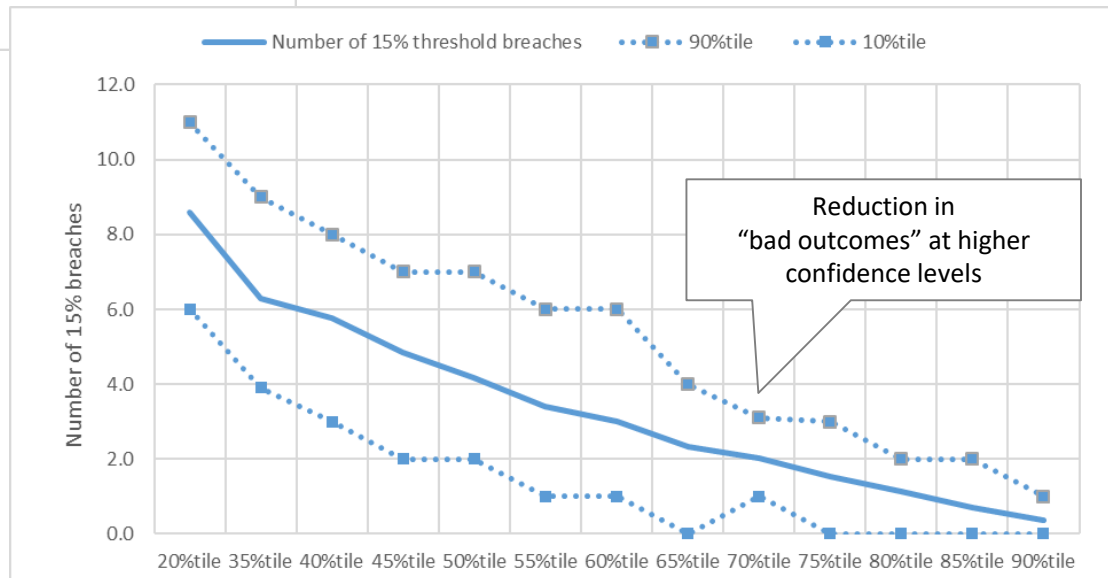| Metric	ICE Confidence Level												
	20%tile	35%tile	40%tile	45%tile	50%tile	55%tile	60%tile	65%tile	70%tile	75%tile	80%tile	85%tile	90%tile
Number of 15% threshold breaches	8.6	6.3	5.8	4.8	4.2	3.4	3.0	2.3	2.0	1.5	1.1	0.7	0.4
Number of 25% threshold breaches	7.1	4.8	4.4	3.5	3.0	2.4	2.1	1.5	1.2	0.9	0.6	0.4	0.2
Average program growth vs. ICE	38%	22%	18%	11%	8%	3%	0%	-5%	-7%	-11%	-16%	-19%	-25%
Average launch delay (months)	33	27	27	19	18	13	10	5	4	0	-1	-3	-6
Spent on Cancelled Programs	7.4%	4.0%	3.4%	2.6%	2.3%	1.3%	1.3%	0.7%	0.7%	0.4%	0.2%	0.1%	0.0%

Simulation Variability

High-Risk Mix: 13 programs, overall σ =28%, 15 year analysis window
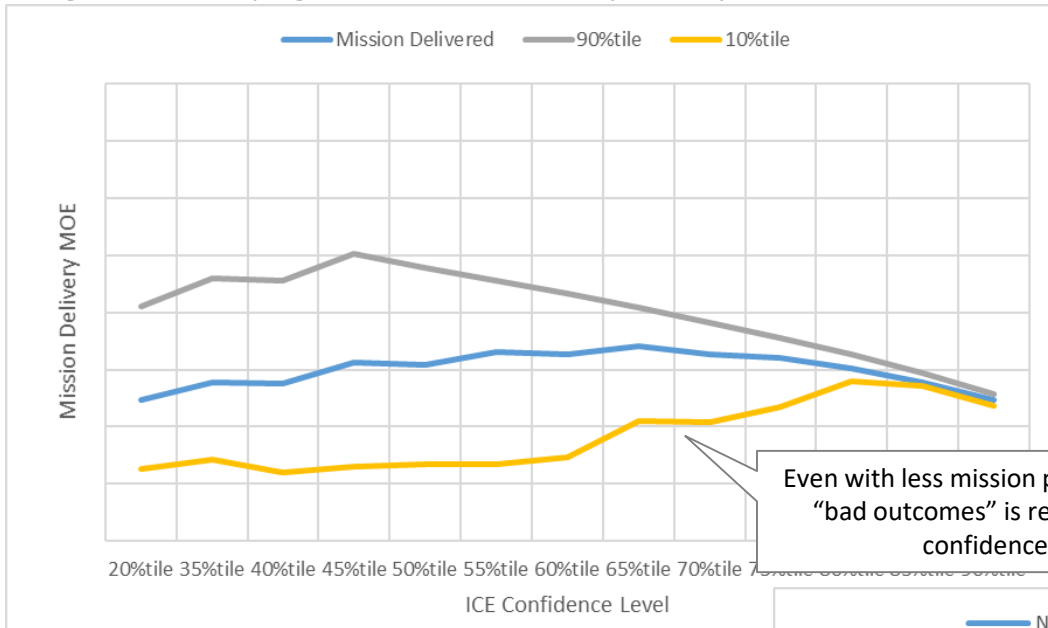
Variability over 250 simulations is tracked because mean doesn't tell the whole story

Even with less mission planned, chance of "bad outcomes" is reduced at higher confidence levels

Reduction in "bad outcomes" at higher confidence levels

Summary and Next Steps

- Analysis of hypothetical portfolios demonstrates linkages between:
  - Amount of mission planned/programmed
  - Amount of mission ultimately delivered
  - Breaches and other growth metrics

- Overly optimistic AND overly pessimistic estimates should be ruled out
  - Due to mission impacts, not just cost/schedule performance
  - Similar to NASA findings

- BEAMS has motivated further analysis of actual portfolios and ICE track record
  - What confidence level have we been estimating?
  - What is relative importance of breaches vs. mission delivery?