NATIONAL RECONNAISSANCE OFFICE

Modeling R&D Budget Profiles

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VIGILANCE FROM ABOVE

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Agenda

- Background
  - Key findings from 2004 put into practice
  - Link between schedule and phasing
- Updated Models
  - Space system phasing model
  - Ground system phasing model
- Estimating with Variable Outlay Rates

Background

- 2004 National Intelligence Authorization Act
  - "Budgeting to the ICE" becomes law
  - Not just total, but every year
  - Increased scrutiny on phasing models

- 2006 IC CAIG and NRO publish new models†
  - Four key enablers identified:

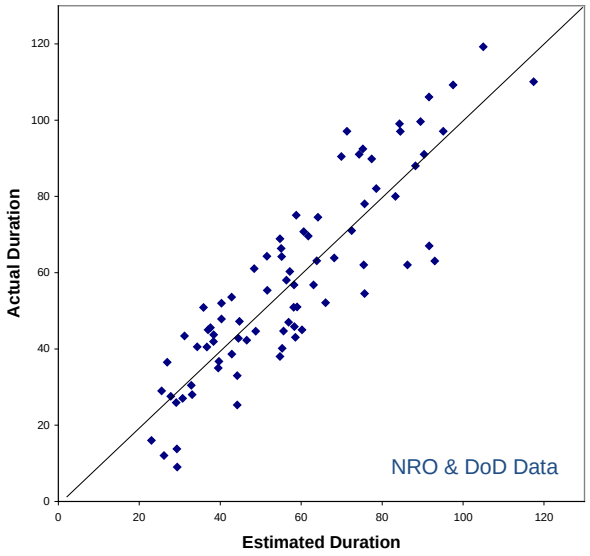
1. New accuracy metrics to defend model results
2. Improved regression methods for incorporating independent variables
3. New schedule models for defining start and end dates
4. Standard process for converting cost to budget

†Burgess, Erik. "R&D Budget Profiles and Metrics." *Journal of Parametrics*, Volume XXV, Summer 2006.

Two Separate Models: Schedule and Phasing

1

Schedule Estimating Relationship (SER)



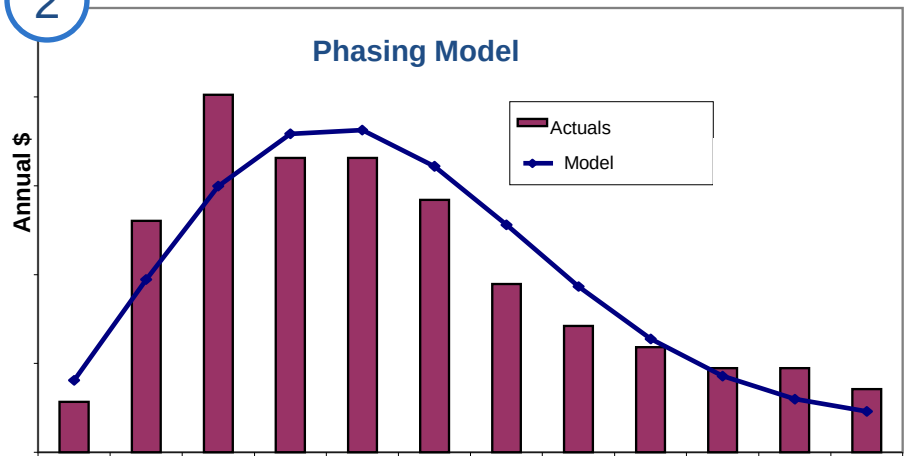
Time to First Launch =
$7.9 + .69W^{.408}DL^{.179} + 11.8MT - 7.1OPT$

W = dry weight (lbs)
DL = design life (months)
MT = # of mission types (usually 1, e.g., comm)
OPT = 1 if contract option

Quality Metrics
$\sigma = 23\%$
$R^2 = .79$
N = 82
Bias = 0%

SER establishes nominal end date for phasing model

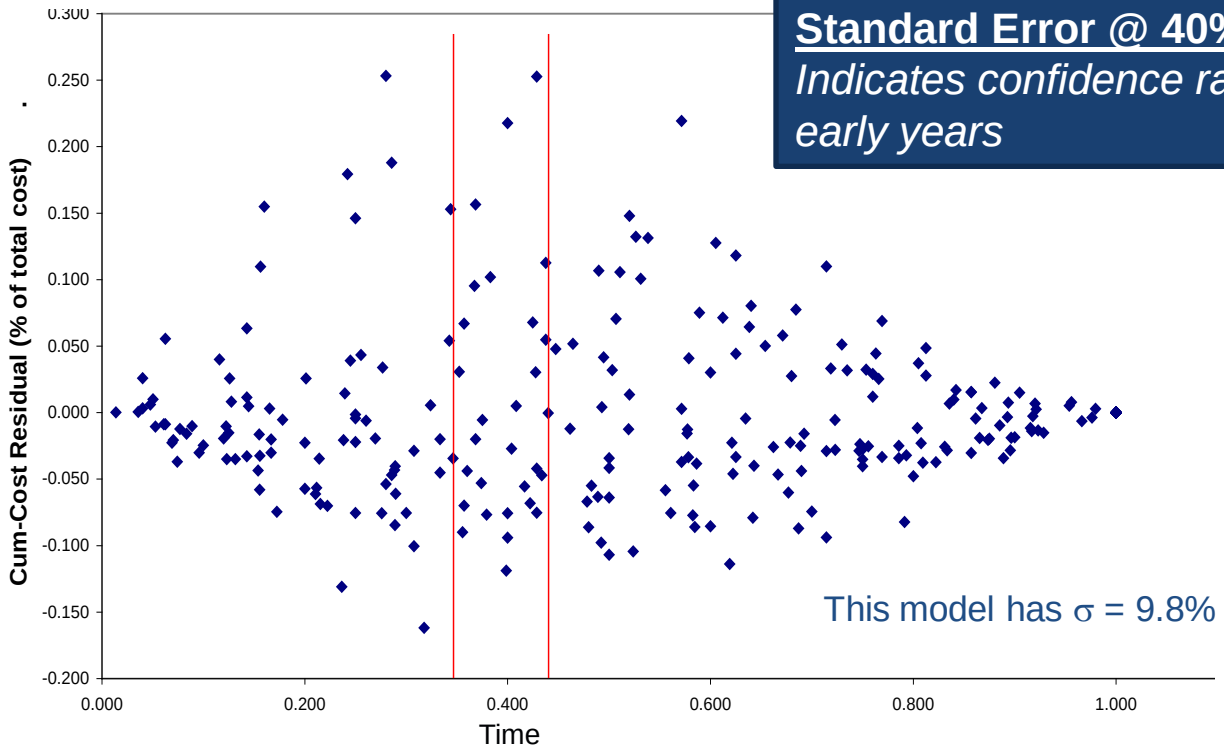
2



In practice, usually not enough money in early years, so what should we do?

- ~~Decrease our cost estimate~~
- Slip schedule
- Argue for more funding

Our Most Powerful Accuracy Metric

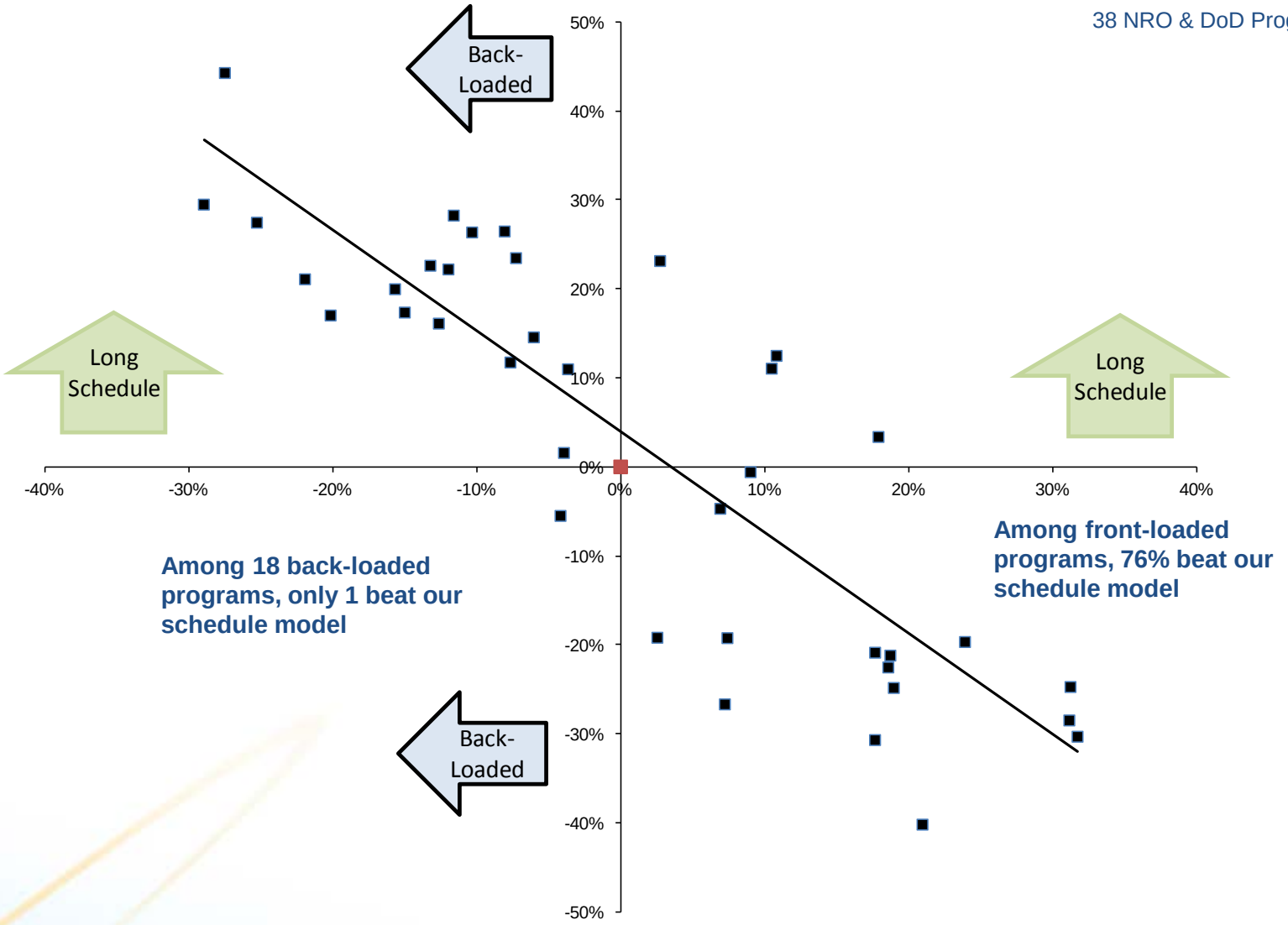


Standard Error @ 40% complete
Indicates confidence range through critical early years

In practice since 2006:

- Phasing model minus 1σ is minimum accepted funding request.
- Program schedules are slipped or funding is added.

Schedule and Phasing Are Linked



Interpretation of These Data

Any prediction that a contract will be completed with both

1. A back-loaded profile, and
2. A schedule faster than the CAIG baseline model

is inconsistent with almost all historical data.

Front-loading the budget is a necessary but not sufficient condition for programs to beat the CAIG schedule model. Other factors contribute to schedule delays.

Scatter along the diagonal reflects error in the phasing model. Perfect phasing would fall on the diagonal due to error in schedule estimating.

These data reflect final profiles and actual schedules, but contain no information on how programs were initially planned.

Satellite Expenditure-Phasing Model

Weibull plus a constant-rate term
38 NRO & DoD Programs
387 time-cost pooled data points

$$E(t) = d\left[\, Rt + 1 - e^{-\alpha\, t^{\beta}} \,\right]$$

$$d = \frac{\text{total cost}}{R + 1\text{-}e^{-\alpha}}$$

$$0 \le t \le 1.0$$

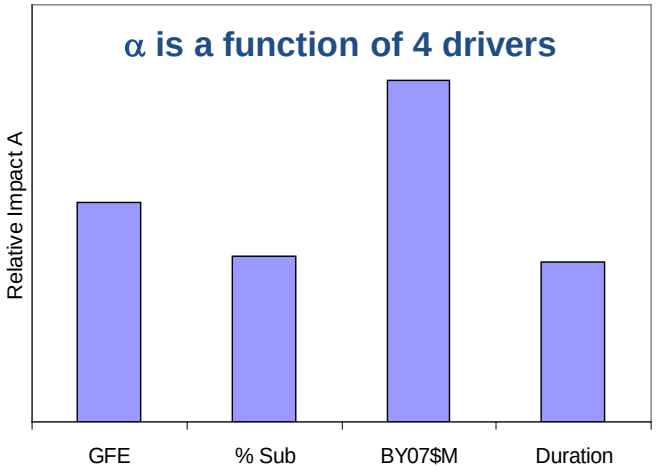
$$\text{R} = .002945 \cdot \text{ duration (mos.)}$$

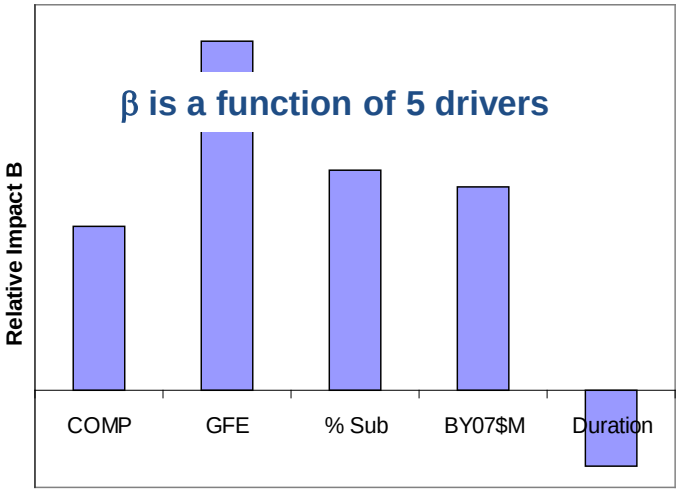
$$\alpha = 0.10 + \sum X_i \cdot \text{driver}_i$$

$$\beta = 1.539 + \sum Y_i \cdot \text{driver}_i$$

Driver	Coefficient (X)
GFE (1,0)	1.84E+00
% Subs	2.73E-02
BY07$M	9.57E-04
Duration (mos)	2.79E-02

Driver	Coefficient (Y)
Competitive (1,0)	1.71E-01
GFE (1,0)	3.62E-01
% Subs	4.47E-03
BY07$M	7.03E-05
Duration (mos)	-1.62E-03





Ground Expenditure-Phasing Model

Weibull plus a constant-rate term
28 IC & DoD Programs
224 time-cost pooled data points

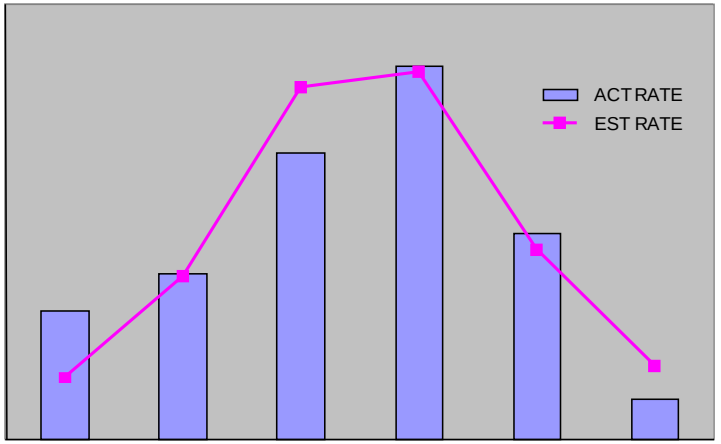
$$E(t) = d\left(Rt + 1 - e^{-\alpha\, t^{\beta}}\right)$$

$$d = \frac{\text{cost at } t = 1.0}{R + 1\text{-}e^{-\alpha}}$$

$$\alpha = 2.41 + 1.17^{\text{Infrastructure or Terminal}}$$

$$\beta = 2.05 + 0.96^{\text{Follow-on}}$$

$$R = .0011 \times (\text{Total Cost, BY09\$M})$$



Gives Range of Profiles Based on Independent Variables

New Infrastructure or Terminal

Front-Loaded 57/50

% Spent @ % time

Back-Loaded 35/50

Follow-on Data Processing, C2, or Mission Management

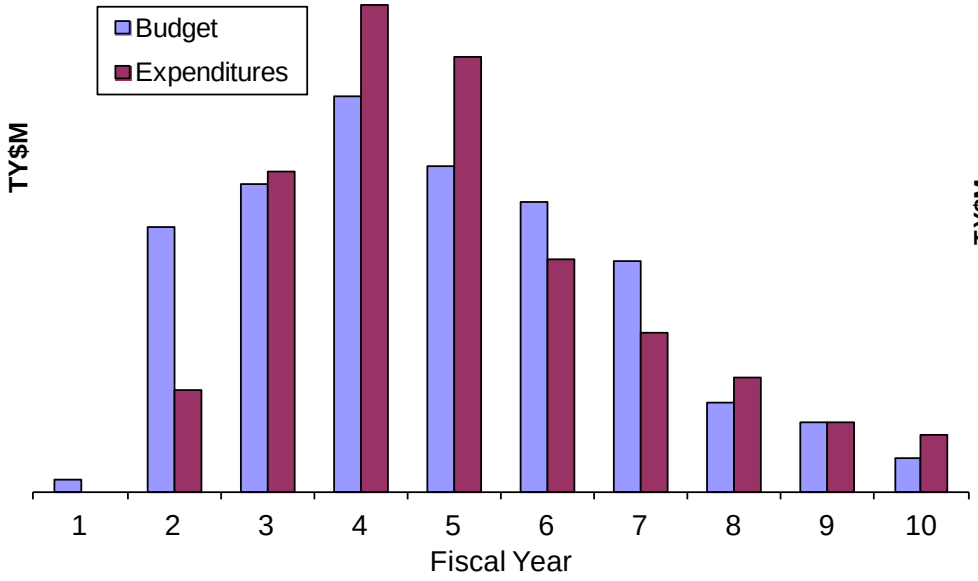
Expenditures ≠ Budget Authority

- NRO CAIG estimates contract costs
  - Final costs – based on actual end-of-program historical data
  - Annual expenditures – based on actual expenditure profiles from completed programs
- Estimated expenditure profile is not a budget profile
  - Budget authority must account for total government liability
  - Difference between budget authority and expenditures is the annual outlay rate
- NRO CAIG and others using published appropriation-wide outlay rates to convert expenditure estimate to budget request
  - Process published by Lee, Hogue, and Gallagher in 1997†
  - Implemented in our models since 2004

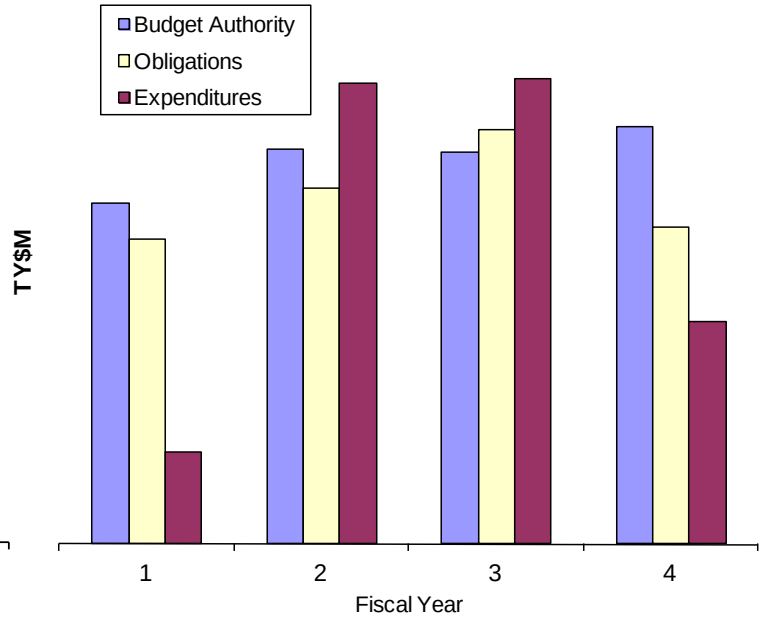
† Lee, David A., Hogue, Michael R., and Gallagher, Mark A. "Determining a Budget Profile from a R&D Cost Estimate," Journal of Cost Analysis, 1997.

Examples

Large Development Contract



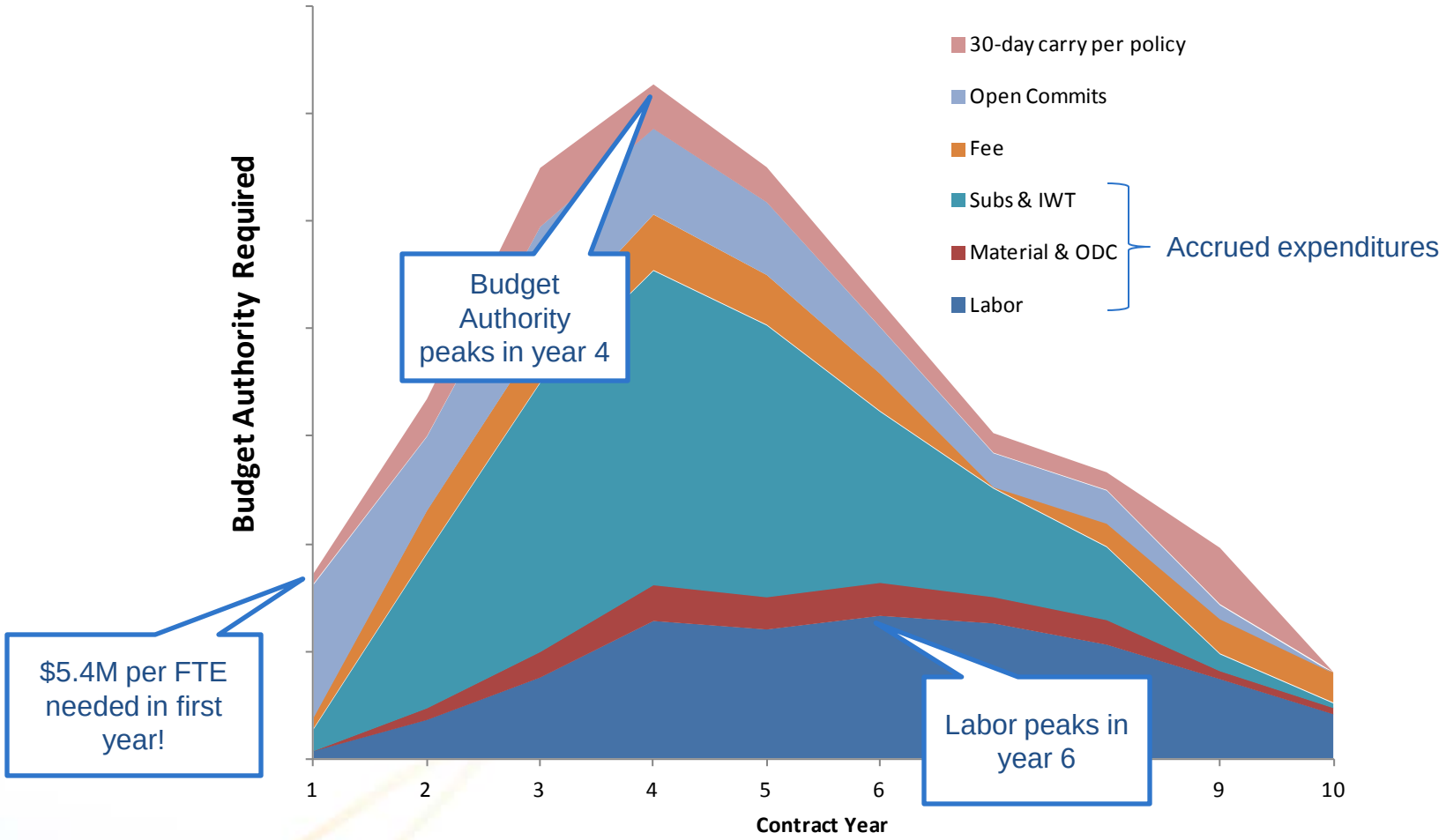
Small Acquisition Contract



- Budget Authority exceeds expenditures in early program years
- Several underlying causes – not just poor performance
- Budgets often appear too front-loaded

What is Budget Authority Used For?

A recently completed satellite contract



Only14% of Ramp-up Budget Authority is In-house Labor Costs

Estimating Outlay Rates

- Outlay rates: Link between expenditures and Budget

$$BA_k = \left(\varepsilon_k - s_2 BA_{k-1} - s_3 BA_{k-2} - \mathrm{L} - s_J BA_{k-J+1}\right) / s_1$$

Outlay rates, s_i, have a large impact on budget in early years

- Appropriation-wide averages may not be appropriate
  - Actual outlay rates vary during life of contract
  - Program structures vary

- CAIG study approach: Collect data via CFSRs
  - Actual government liability and expenditures each year
  - Compare across contracts, over time, etc.

Approach neutralizes effects of excessive or inadequate budget authority.

Basis for Analysis

Example: Actual first year of Example contract. CFSR through September.

		Year 1
12)	a) Open Commitments (CUM)	26,720
	b) Accrued Expenditures (CUM)	23,149
	c) Fee (CUM)	2,836
	d) Total (CUM) (12a+12b+12c)	52,705
13)	Estimated Termination Cost	1,100
14)	Total Govt Liability (12d+13)	53,805
	Incremental w/o Term Liability	15,439
15)	Forecast of Billings to Govt (CUM)	23,169

"Exact" budget has TOA matching line 14. True budget must have been greater or equal to liability.

This is the actual amount billed that year

$23,169 / $53,805 = 43% of liability was billed

- In this example, "exact" budget would have a 43% year-1 outlay rate.
- Actual TOA cannot be lower than liability (by law).
- Actual outlay couldn't have been higher than 43%.

NRO Funding Policy

CBP-20, 30 June 2010

- Request obligation authority for additional 1 month of budget authority (carry forward)

		CFSR Year 1	
12)	a) Open Commitments (CUM)	26,720	*27,934*
	b) Accrued Expenditures (CUM)	23,149	*32,199*
	c) Fee (CUM)	2,836	*3,939*
	d) Total (CUM) (12a+12b+12c)	52,705	*64,072*
13)	Estimated Termination Cost	1,100	*1,100*
14)	Total Govt Liability (12d+13)	53,805	***65,172***
	Incremental w/o Term Liability	15,439	*11,367*
15)	Forecast of Billings to Govt (CUM)	23,169	***23,169***

Additional 1 month of projected liability

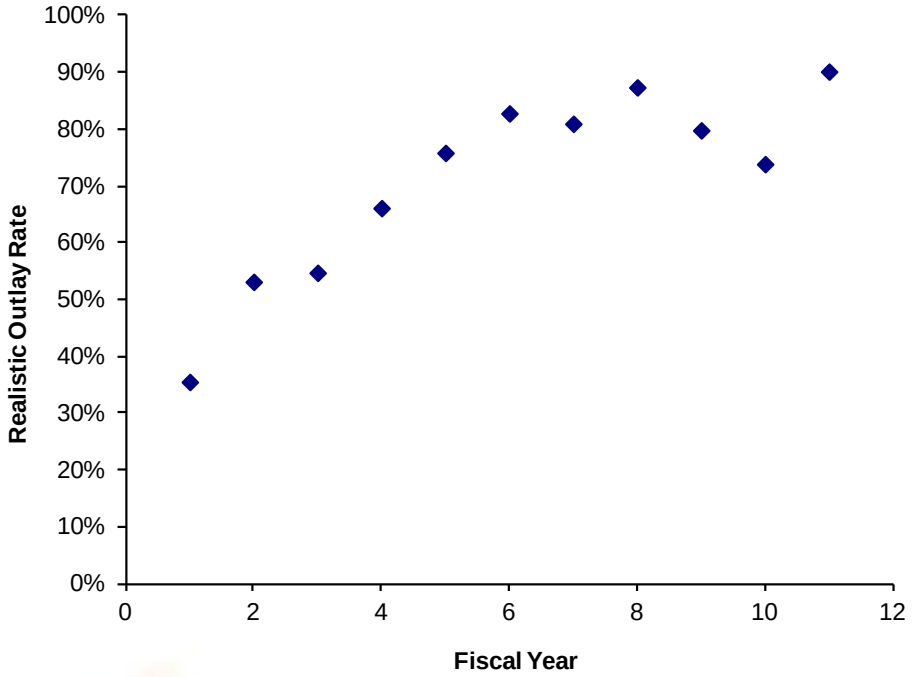
Same end-of year billing

$23,169 / $65,172 = 36% of liability was billed

- In this example, “realistic” budget would have a 36% year-1 outlay rate.
- Actual budget may have been higher

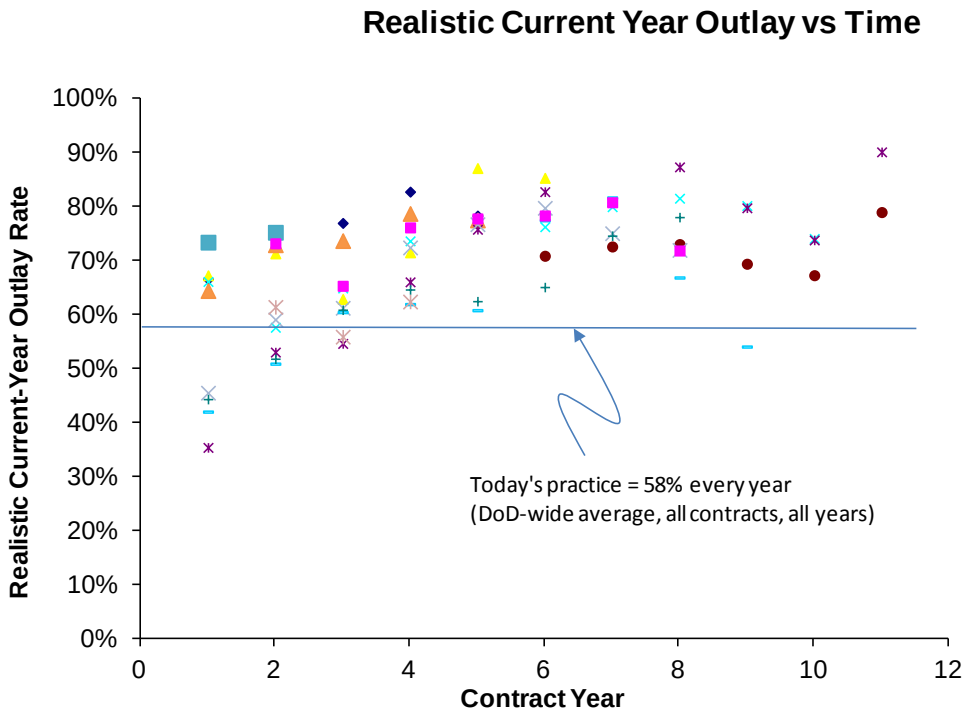
Result for One Contract

- Realistic outlay rate computed each year
- Assume oldest money expended first



- These are Realistic Annual Outlay Rates Assuming an "Exact" Budget
- Consistent with goal for Agency Cost Position & NRO Policy
- Consistent with actual program execution

Multiple Programs vs. Time



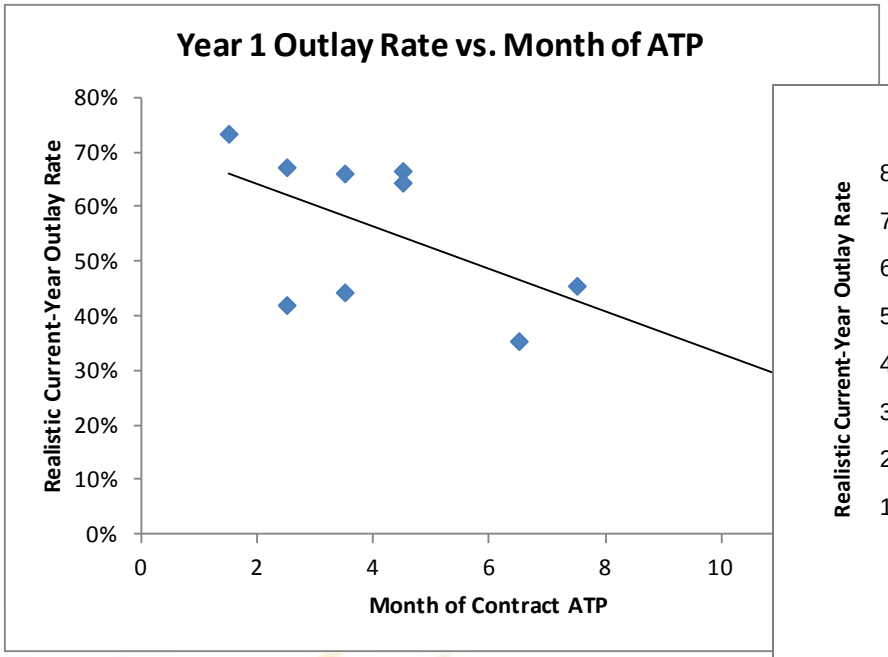
- Outlay rates increase gradually over the life of a contract
  - Less open commitments and termination liability
  - Less overall funds needed in future periods
- Difference among programs is highest in first few years

Application to Program Estimates

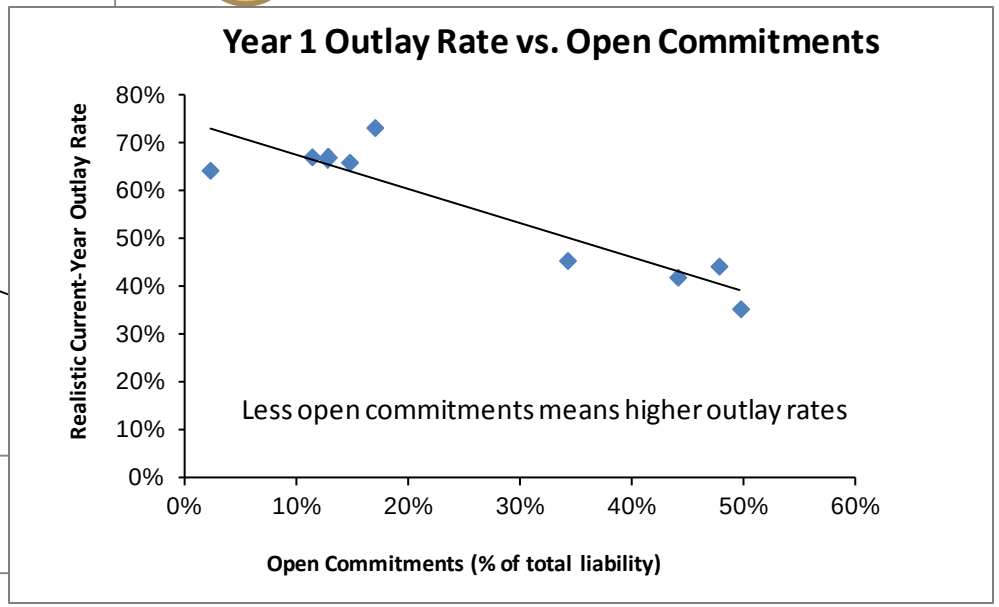
We must predict outlay rates to use in estimates

Two programmatic factors affect first-year outlay rate:

1. Month of ATP during the fiscal year



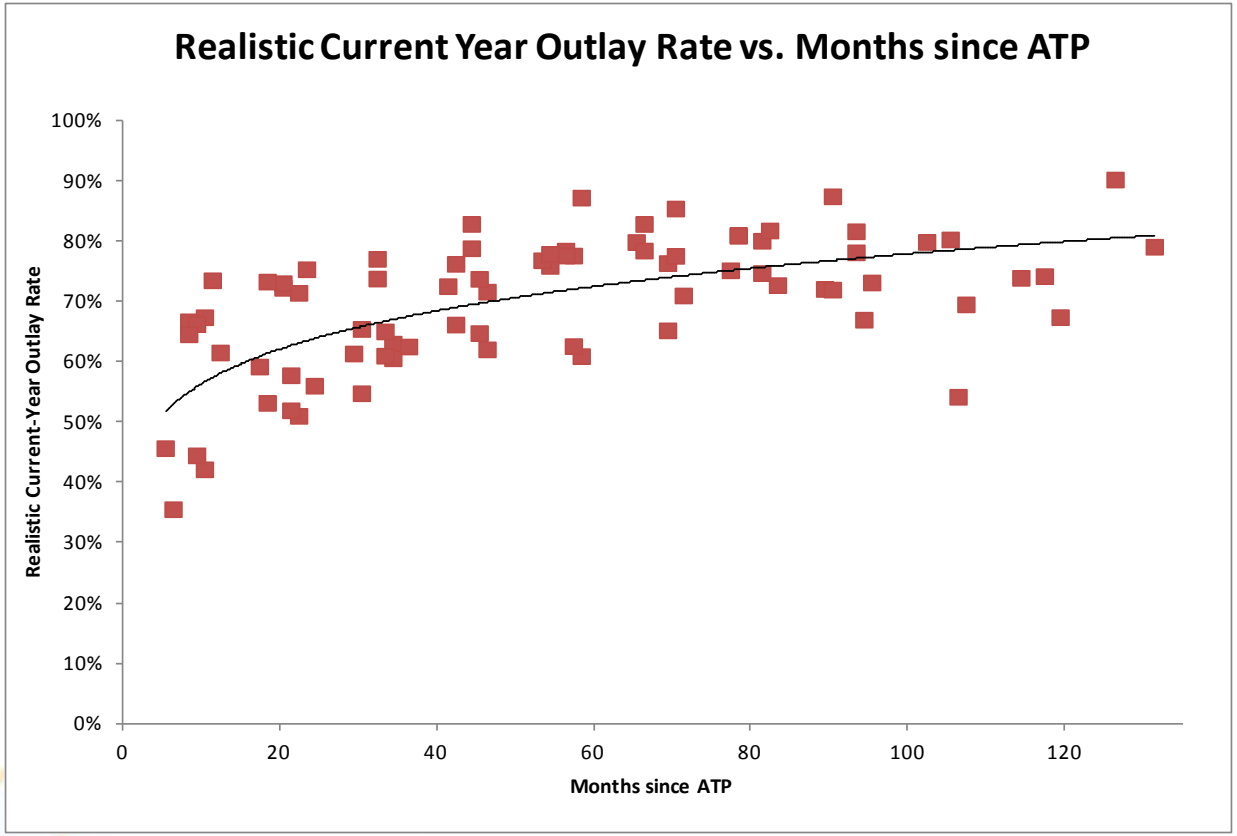
2. Open commitments



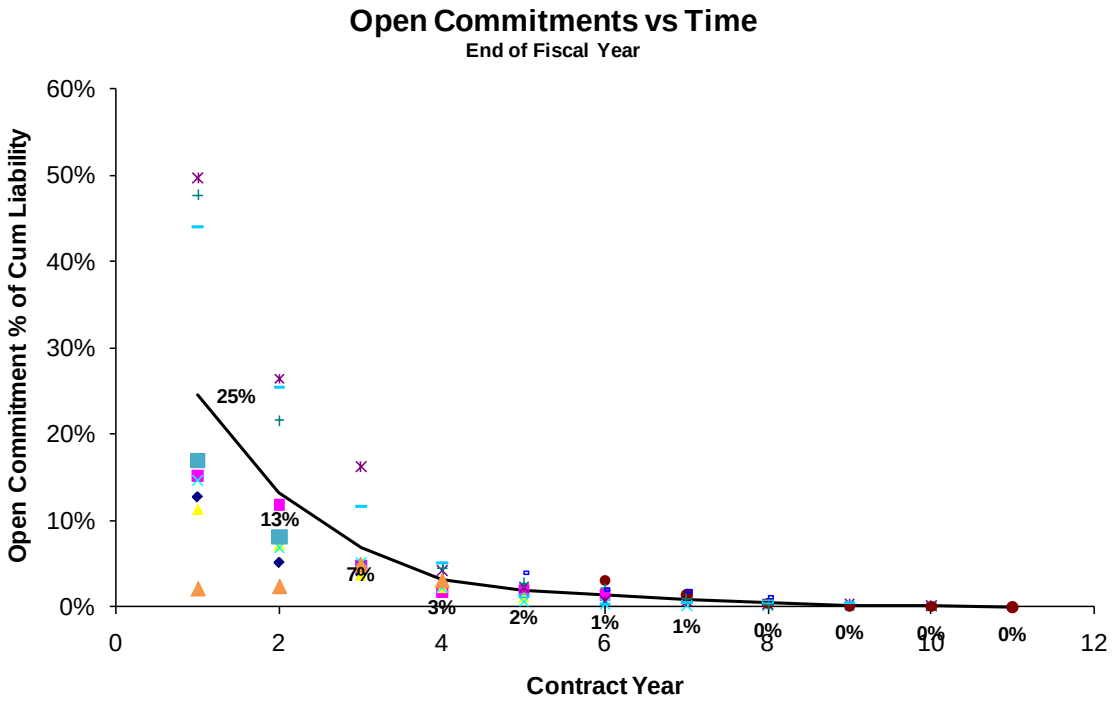
Note: These factors are correlated at 0.30

(1) Months Since ATP

- Affects later years as well
- Increasing trend can be modeled as a continuous function
- Implemented in space-segment phasing tool

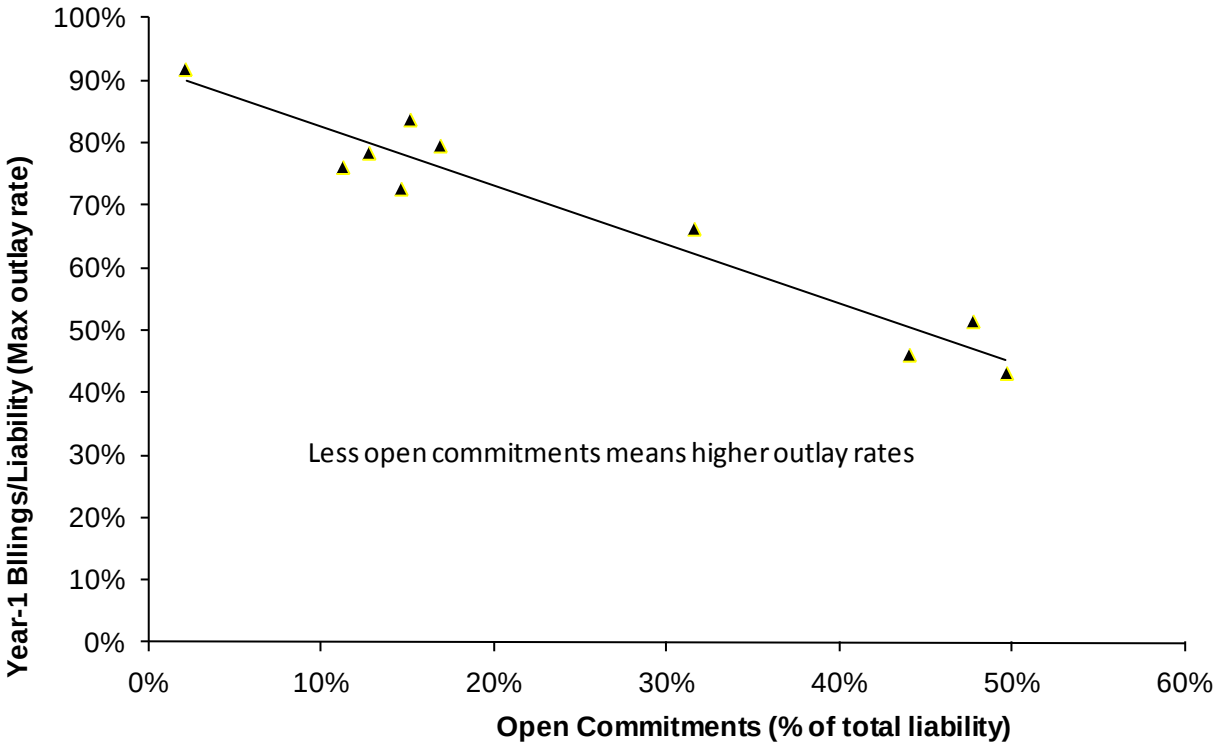


(2) Open Commitments Vs. Time



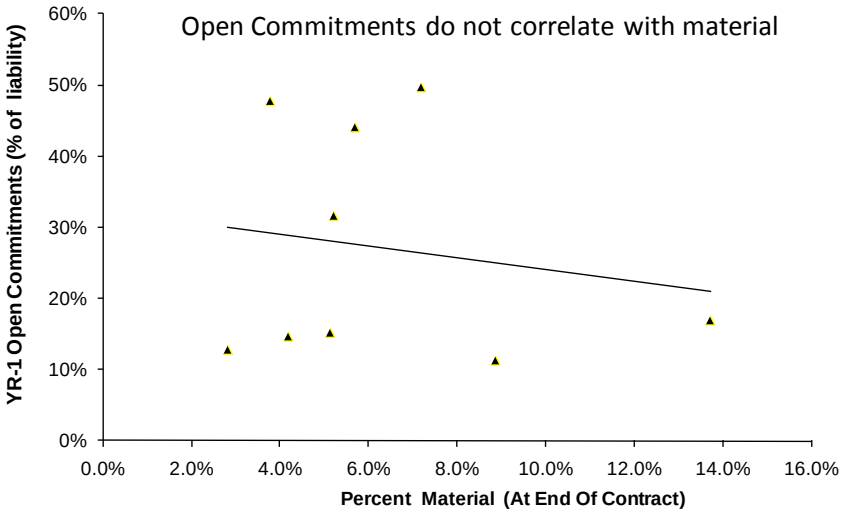
- Open commitments can be a high percentage of total liability in early years.
- At end of contract, vendors are delivering products, subcontracts contracts are closing out, new commitments are slowing.

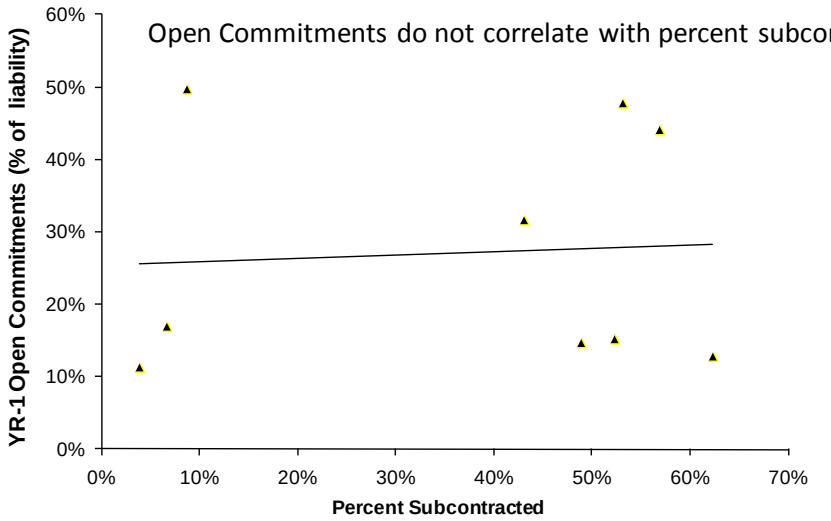
Open Commits Drive Outlay Rates

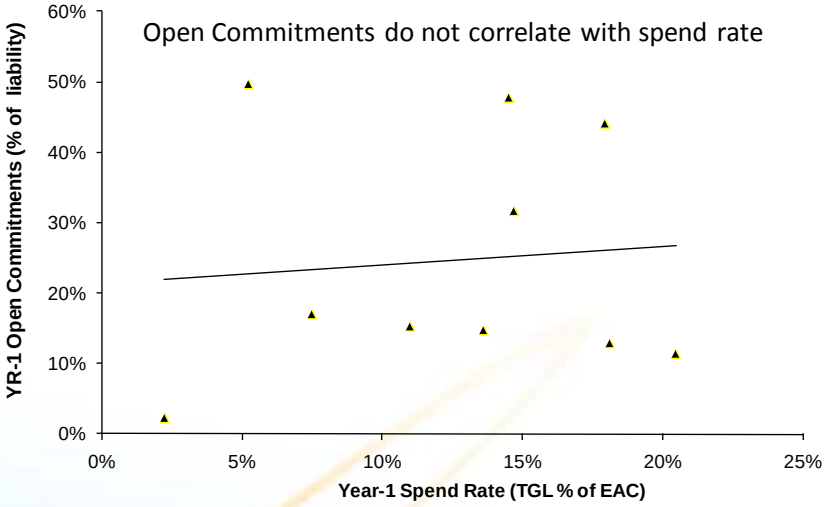


High level of open commitments drives outlay rates down.

What Drives Open Commitments?







Open commitments are driven by other factors

- Subcontract funding terms
- Accounting practices

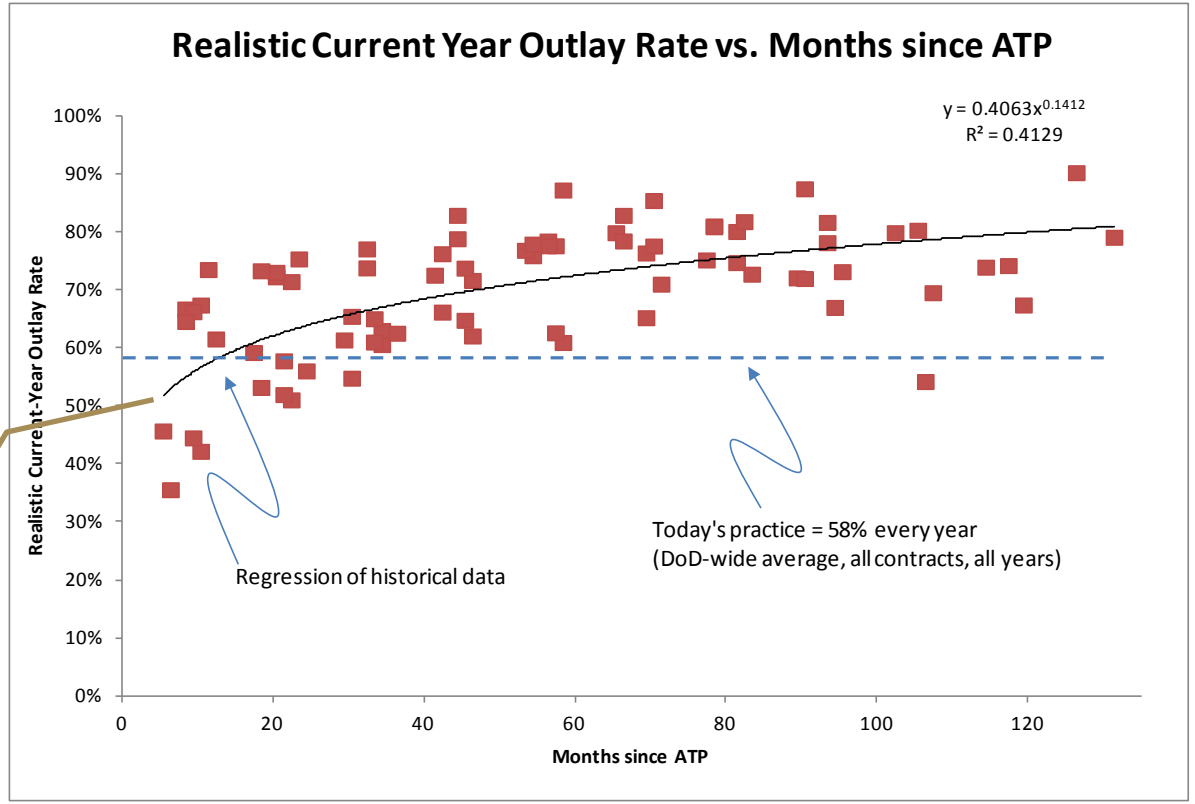
Predicting year-1 open commitments is difficult.

Same result for other years.

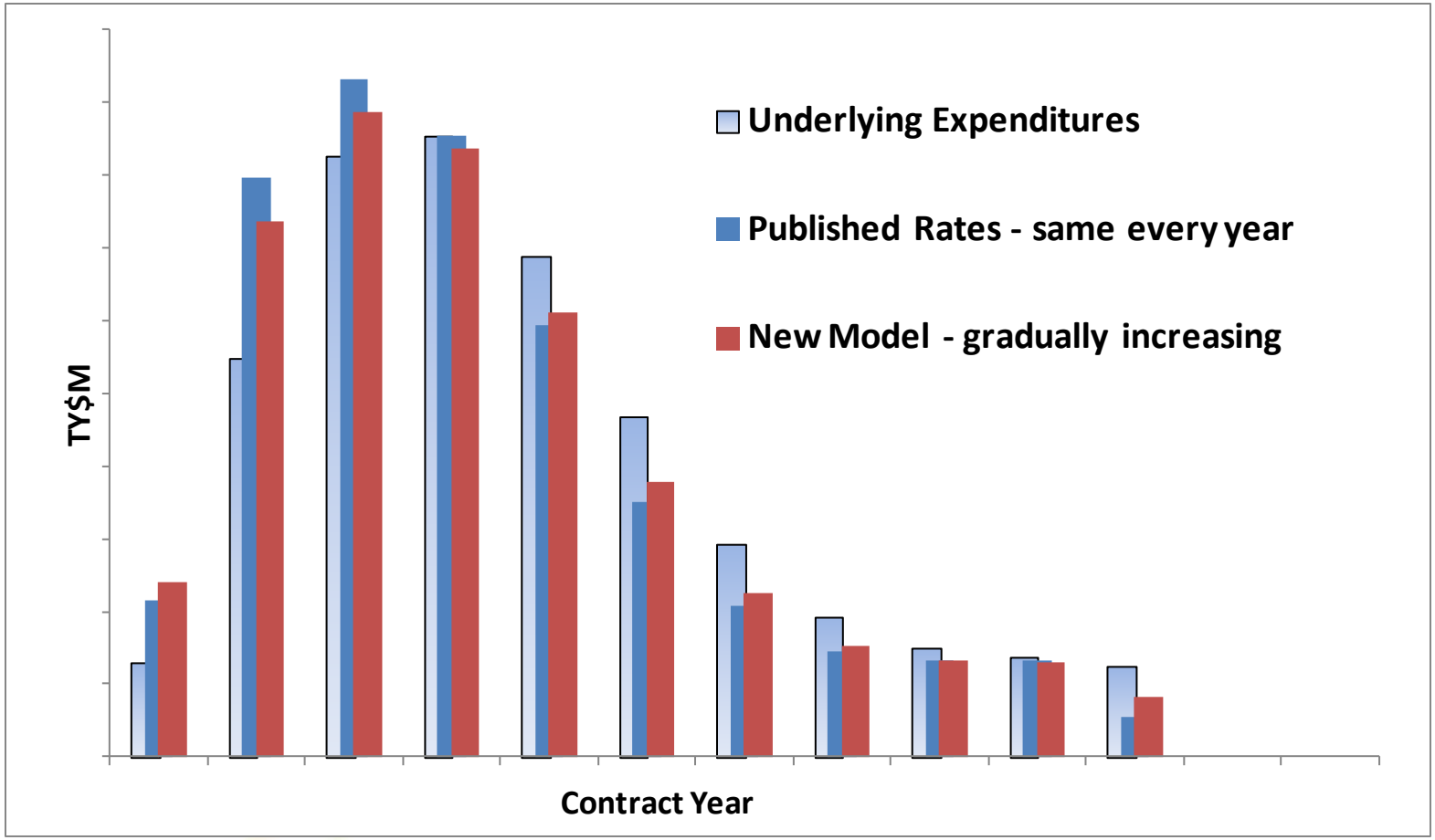
CAIG's New Estimating Practice

- Avoid fixed outlay rates
- Use rates that increase during contract life.
- Allow tailoring to account for low or high open commitments.

- Implement this curve in phasing tool.
- Allow tailoring – points above curve have low open commits.



Impact on Estimates: Example



Profile is less peaked

New Phasing Tool

(Available to Industry)

- Allow users to input outlay rates by year
- Default to regression of historical data
- Adjusts weighted index for accurate BY-TY conversion

(2) Apply budget constraints as necessary
(3) Compute resulting deviation from underlying model

Linked Inputs:

1

Space		Ground
2015	**Fiscal-year start**	2015
2025	**Fiscal-year end**	2025

2

Expenditures in base-year dollars (BY$): BY 2010

Fiscal Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Space	79	283	397	390	301	197	119	77	59	54	43	0
Ground	10	34	27	11	4	3	3	3	3	3	1	0

3

Outlay rates: **Space** default

	Year 1	Year 2	Year 3	Year 4	Year 5	check
2015	53.00%	47.00%	0.00%	0.00%	0.00%	100.00%
2016	54.00%	46.00%	0.00%	0.00%	0.00%	100.00%
2017	58.00%	42.00%	0.00%	0.00%	0.00%	100.00%
2018	64.00%	36.00%	0.00%	0.00%	0.00%	100.00%
2019	63.00%	37.00%	0.00%	0.00%	0.00%	100.00%
2020	67.00%	33.00%	0.00%	0.00%	0.00%	100.00%
2021	69.00%	31.00%	0.00%	0.00%	0.00%	100.00%
2022	70.00%	30.00%	0.00%	0.00%	0.00%	100.00%
2023	61.00%	39.00%	0.00%	0.00%	0.00%	100.00%
2024	61.00%	39.00%	0.00%	0.00%	0.00%	100.00%
2025	61.00%	39.00%	0.00%	0.00%	0.00%	100.00%
2026	61.00%	39.00%	0.00%	0.00%	0.00%	100.00%
2027	61.00%	39.00%	0.00%	0.00%	0.00%	100.00%
2028	61.00%	39.00%	0.00%	0.00%	0.00%	100.00%
2029	61.00%	39.00%	0.00%	0.00%	0.00%	100.00%

Ground

	Year 1	Year 2	Year 3	Year 4	Year 5	check
2015	58.56%	34.53%	4.07%	1.71%	1.13%	100.00%
2016	58.56%	34.53%	4.07%	1.71%	1.13%	100.00%
2017	58.56%	34.53%	4.07%	1.71%	1.13%	100.00%
2018	58.56%	34.53%	4.07%	1.71%	1.13%	100.00%
2019	58.56%	34.53%	4.07%	1.71%	1.13%	100.00%
2020	58.56%	34.53%	4.07%	1.71%	1.13%	100.00%
2021	58.56%	34.53%	4.07%	1.71%	1.13%	100.00%
2022	58.56%	34.53%	4.07%	1.71%	1.13%	100.00%
2023	58.56%	34.53%	4.07%	1.71%	1.13%	100.00%
2024	58.56%	34.53%	4.07%	1.71%	1.13%	100.00%
2025	58.56%	34.53%	4.07%	1.71%	1.13%	100.00%
2026	58.56%	34.53%	4.07%	1.71%	1.13%	100.00%
2027	58.56%	34.53%	4.07%	1.71%	1.13%	100.00%
2028	58.56%	34.53%	4.07%	1.71%	1.13%	100.00%
2029	58.56%	34.53%	4.07%	1.71%	1.13%	100.00%

New section computes rates based on time since ATP. Allows tailoring.

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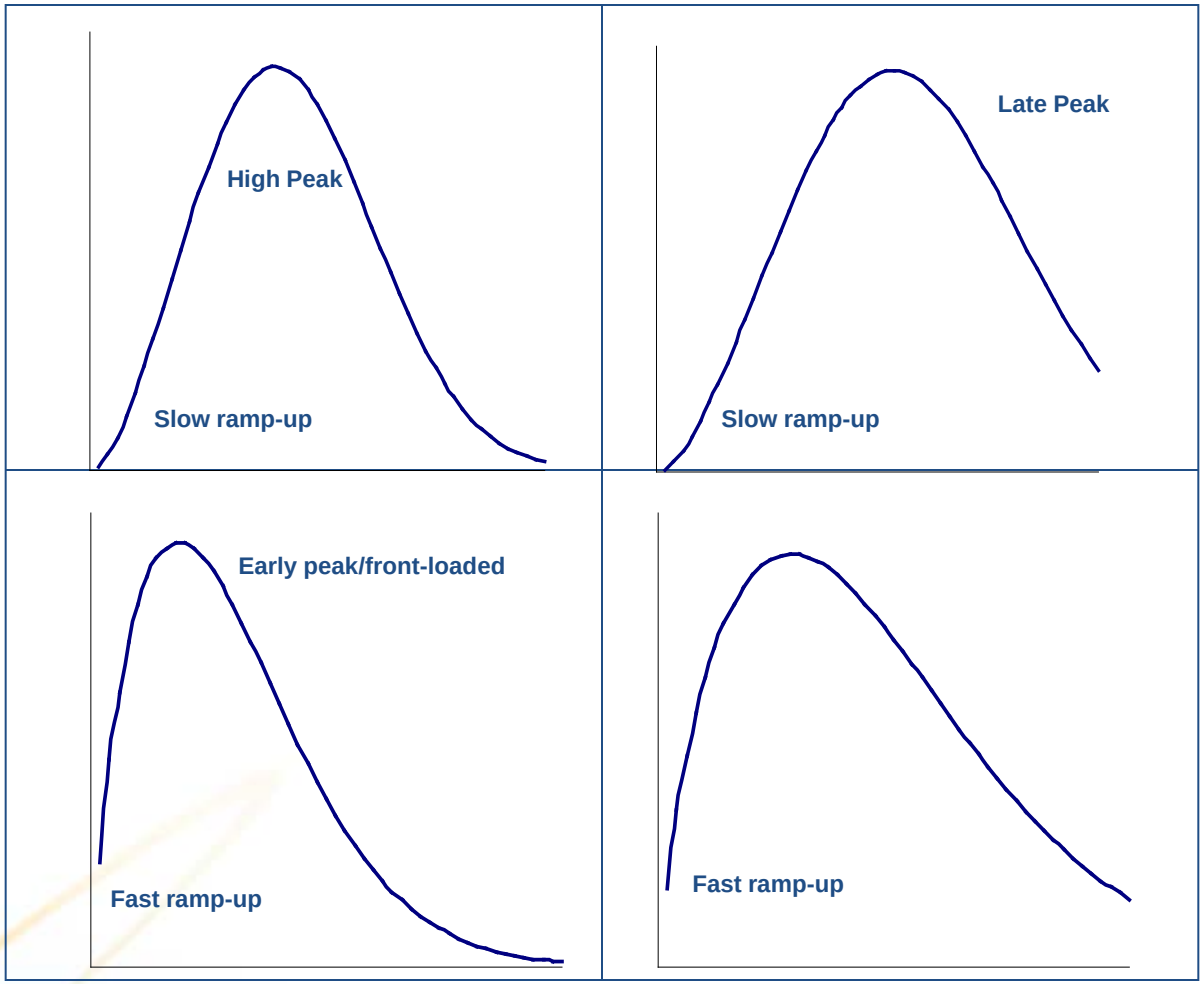
Definition of Terms

- Actual Max Outlay Rate – cumulative forecast of billings to the government divided by the total government liability. This rate demonstrates the maximum percentage of budget a program manager could spend in a given period, assuming access to a perfect cost estimate.
- Realistic Outlay Rate – calculated similarly to the max outlay rate except forecast of billings and total liability information estimated one month from current period.
- Open Commitments – payment obligations legally binding the government to make payment in a given period.
- Accrued Expenditures – authorized charges against available funds.
- Estimated Termination Cost – the cost to the government of terminating a program prior to fulfillment of terms by the contractor.
- Forecast of Billings to Government – expected amount to be invoiced to the government in a given period.
- Percent Subcontracted – generally calculated here as total burdened subcontractor cost divided by total cost through G&A, when such program data is available.

Interpretation of α, β



ALPHA: Moves peak forward/backward

BETA: Drives initial slope