## Accidental Proof of Calculus for Cost Analysts



#### Professional Development & Training Workshop May 16-18, 2023 🐵 San Antonio, Texas



AFRL/FZC

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# Purpose





### Purpose

### Calculus

More Than a Merrit Badge

Tools of the Trade

- 1 Pencil & Paper 11 0
  - Calculator
  - MATLAB

Cautionary Reminder
Cross Checks





# Background

## Phasing & Problem Origin





#### Phasing

- Spread Estimate Across Time
  - Inflation & Escalation
- Align Funding with Needs
- Minimize Forward Financing







#### Phasing Calculator

- Flat Level of Effort (LOE)
- Front Loaded Phasing Distributions
  - Beta
  - Raleigh
  - Weibull
- Outsource the Math
  - Input
    - BY\$M Input
    - Start Date (Calendar Year)
    - Duration (Months)
    - Phasing profile shape parameters
  - Output
    - TY\$M or percentages
    - Costs Bucketed into Fiscal Years







#### Problem Origin

- Colleague asked for a feature
- Instead of a Flat Uniform Level of Effort (LoE)
- Ramp up to a LoE across a number of years



• EZ PZ







## The Math

### Quick Pass & Cross Check



#### 1<sup>st</sup> Step

#### • Sketch out the problem

- Constraints:
  - Start month = 0
  - Ramping period = 36 months
  - Full Level of Effort @ Month 37
- Writing the equations
  - Variables







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AFRL

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    - Costs Bucketed into Fiscal Years
- Demo @ End









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# Calculus

# Area Under the Curve

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# Area Under the Curve

• Tabulated Integral Reference:

$$\int x^n dx = \frac{1}{n+1} * x^{n+1} + C$$













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$$\int x^n dx$$

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 $x^{n+1}$ 

 $\overline{n+1}$ 





$$\int x^n dx = x^n$$

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 $\overline{n+1}$ 

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 $x^{n+1}$ 





$$\int x^n dx = x^{n+1}$$

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$$\int x^n dx = \frac{1}{n+1} * x^{n+1}$$

C





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$$\int x^n dx = \frac{1}{n+1} * x^{n+1} + C$$







$$\int x^n dx = \frac{1}{n+1} * x^{n+1} + C$$





$$\int \frac{1}{36} * x^n dx = \frac{1}{n+1} * x^{n+1} + C$$





$$\frac{1}{36} * \int x^n dx = \frac{1}{n+1} * x^{n+1} + C$$





















$$\frac{1}{36} * \int x^1 \, dx = \frac{1}{1+1} * x^{1+1} + C$$















$$\frac{1}{36} * \int x^1 dx = \frac{1}{36} * \left[ \frac{1}{2} * x^2 + C \right]$$







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$$\frac{1}{36} * \int_{a}^{b} x^{1} dx = \frac{1}{36} * \left[ \frac{1}{2} * \frac{b^{2}}{2} \right]_{a} x^{2} a$$







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$$= \frac{1}{36} * \left[ \frac{1}{2} * b^2 \right]$$









#### Area Under the Curve



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Curiosity



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$$f_x = \left[ \left( \left( \boldsymbol{S} * \boldsymbol{C} \right) - \left( \boldsymbol{S} * \boldsymbol{P} \right) \right) * \left( \frac{\boldsymbol{C} - \boldsymbol{P}}{12} \right) \right] * \frac{1}{2} + \left[ \left( \boldsymbol{S} * \boldsymbol{P} \right) * \left( \frac{\boldsymbol{C} - \boldsymbol{P}}{12} \right) \right]$$











Months





Months







Months

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(12 Months)

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Current Fiscal Year = C Max Month

Slope = S



=(((\$B\$2\*AT3)-(\$B\$2\*AS3))\*(AT3-AS3)/12)\*0.5+((\$B\$2\*AS3)\*(AT3-AS3)/12)

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(12 ivionths)

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Current Fiscal Year = C Max Month

Slope = S



=(((\$B\$2\*AT3)-(\$B\$2\*AS3))\*(AT3-AS3)/12)\*0.5+((\$B\$2\*AS3)\*(AT3-AS3)/12) CUBEKPIM... X  $\checkmark$ tx AK AL AM AAA AQ AR AT AU AV AW B AA AB AC AD AE AF AG AH AI AJ AS AX AY Ramp Period 36 2 Slope (S) 0.02777778 Annualized Table FY0 FY1 FY2 FY3 FY4 Total 3 13 1 25 36 Months 0 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 Max Month / FY 3% 8% 8% Cross Check <del>0%</del> <del>6%</del> 17% 8% 8% 8% <del>0%</del> 3% <del>6%</del> 8% 17% 8% Midpoint 12 Algebra 0% 0% 1.500000 8% 8% 8% 8% Calculus 0% 19% 53% 78% 1.500 13 0% 12) 8% 8% 8% 8% Algebra 53% 78% 1.500 15

**TEVIOUS FISCAL YEAR** = P Max Month

(12 Months)

Current Fiscal Year = C Max Month

$$Slope = S$$

Months

Next Slide





Next Slide

Current Fiscal Year = C Max Month

$$Slope = S$$



# Simplify

## Proof

Presented at the ICEAA 2023 Professional Development & Training Workshop - www.iceaaonline.com/sat2023



$$f_x = \left[ \left( \left( S * C \right) - \left( S * P \right) \right) * \left( \frac{C - P}{12} \right) \right] * \frac{1}{2} + \left[ \left( S * P \right) * \left( \frac{C - P}{12} \right) \right]$$





$$f_x = \left[ \begin{array}{c} \mathbf{S} * \left( \left( \mathbf{C} \right) - \left( \mathbf{P} \right) \right) * \left( \frac{\mathbf{C} - \mathbf{P}}{12} \right) \right] * \frac{1}{2} + \left[ \left( \mathbf{S} * \mathbf{P} \right) * \left( \frac{\mathbf{C} - \mathbf{P}}{12} \right) \right] \right]$$





















































$$f_{x} = \frac{1}{2} * \frac{1}{12} * S * \left[ \left( (C - P) * (C - P) \right) + \left( (2PC - 2P^{2}) \right) \right]$$





$$f_x = \frac{1}{2} * \frac{1}{12} * S * \left[ \left[ \left( \begin{array}{c} e - P \right) * \left( \begin{array}{c} e - P \right) \end{array} \right] + \left[ \left( 2PC - 2P^2 \right) \right] \right] \right]$$





$$f_x = \frac{1}{2} * \frac{1}{12} * S * \left[ \left[ \left( \begin{array}{c} e^{-P} \right) * \left( \begin{array}{c} e^{-P} \right) \end{array} \right] + \left[ \left( \left( 2PC - 2P^2 \right) \right] \right] \right]$$





$$C^{2} - PC - PC$$

$$f_{x} = \frac{1}{2} * \frac{1}{12} * S * \left[ \left[ \left( C - P \right) * \left( C - P \right) \right] + \left[ \left( 2PC - 2P^{2} \right) \right] \right]$$





$$C^{2} - PC - PC + P^{2}$$

$$f_{x} = \frac{1}{2} * \frac{1}{12} * S * \left[ \left[ \left( C - P \right) * \left( C - P \right) \right] + \left[ \left( 2PC - 2P^{2} \right) \right] \right]$$





$$f_x = \frac{1}{2} * \frac{1}{12} * S * \left[ \begin{bmatrix} C^2 & -2PC & +P^2 \end{bmatrix} + \left[ (2PC - 2P^2) \end{bmatrix} \right]$$

$$(\boldsymbol{C}-\boldsymbol{P})*(\boldsymbol{C}-\boldsymbol{P})$$





$$f_x = \frac{1}{2} * \frac{1}{12} * S * \begin{bmatrix} C^2 & -2PC & +P^2 & +2PC - 2P^2 \\ C^2 & -2PC & +P^2 & +2PC - 2P^2 \end{bmatrix}$$























$$f_x = \frac{1}{2} * \frac{1}{12} * S *$$





$$f_x = \frac{1}{2} * \frac{1}{12} * S * \begin{bmatrix} C^2 - P^2 \end{bmatrix}$$

$$\int_{a}^{b} \frac{1}{36} * x \, dx = \frac{1}{36} * \frac{1}{2} * \left[ b^2 - a^2 \right]$$





$$f_x = \frac{1}{2} * \frac{1}{12} * \frac{1}{36} * \begin{bmatrix} C^2 - P^2 \\ \ddots \\ * \end{bmatrix}$$

$$\int_{a}^{b} \frac{1}{36} * x \, dx = \frac{1}{36} * \frac{1}{2} * \left[ b^2 - a^2 \right]$$





$$f_x = \frac{1}{36} * \frac{1}{2} * \begin{bmatrix} \mathbf{C}^2 - \mathbf{P}^2 \end{bmatrix} * \frac{1}{12}$$

$$\int_{a}^{b} \frac{1}{36} * x \, dx = \frac{1}{36} * \frac{1}{2} * \left[ b^2 - a^2 \right]$$

-----





$$f_{x} = \frac{1}{36} * \frac{1}{2} * \begin{bmatrix} C^{2} - P^{2} \end{bmatrix} * \frac{1}{12}$$

$$\int_{a}^{b} \frac{1}{36} * x \, dx = \frac{1}{36} * \frac{1}{2} * \begin{bmatrix} b^{2} - a^{2} \end{bmatrix} * \frac{1}{12}$$

Next Slide



### The Accidental Proof of Calculus for Cost Analysts

- EZ Way
  - More Than a Merrit Badge

$$\int_{0}^{36} \frac{1}{36} x dx = \left[\frac{1}{36} * \frac{1}{2} * x^{2}\right]_{0}^{36} \div 12 = 1.5$$

• The Hard Way



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## The End

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### Purpose

#### Calculus

• More Than a Merrit Badge

Tools of the Trade

- 1 Pencil & Paper 11 0
  - Calculator
  - MATLAB

Cautionary Reminder
Cross Checks





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## Discussion

THE AIR FORCE RESEARCH LABORATORY



## Quotes

#### Expert: 01 010000 01 11 1 0ft00001 ft 0 1 0 0 11 0

### Someone who's made every mistake in a narrow field

## Engineers:

## Solving problems you didn't know you had



##


# Discussion

THE AIR FORCE RESEARCH LABORATORY



## Quotes

#### Expert: 01 0100000 01 11 1 0 fb000

#### Someone who's made every mistake in a narrow field

## Engineers:

### Solving problems you didn't know you had





# 

# Integrals Into Excel

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#### Integrals into Excel *Reminder*

$$\int x^n dx = \frac{1}{n+1} * x^{n+1} + C$$





#### Integrals into Excel *Reminder*

$$\int x^n dx \, = \, \frac{1}{n+1} \, * \, x^{n+1} \, + \, C$$

$$\frac{1}{36} * \left[ x^{1} dx \right] = \frac{1}{36} * \left[ \frac{1}{2} * x^{2} \right] = \frac{1}{36} * \left[ \frac{1}{2} * b^{2} \right] - \frac{1}{36} * \left[ \frac{1}{2} * a^{2} \right]$$
  
The AIB FORCE RESEARCH LABORALY de ICEA A 2002 Declared Dark lemma & Tening Workshop (1992)

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