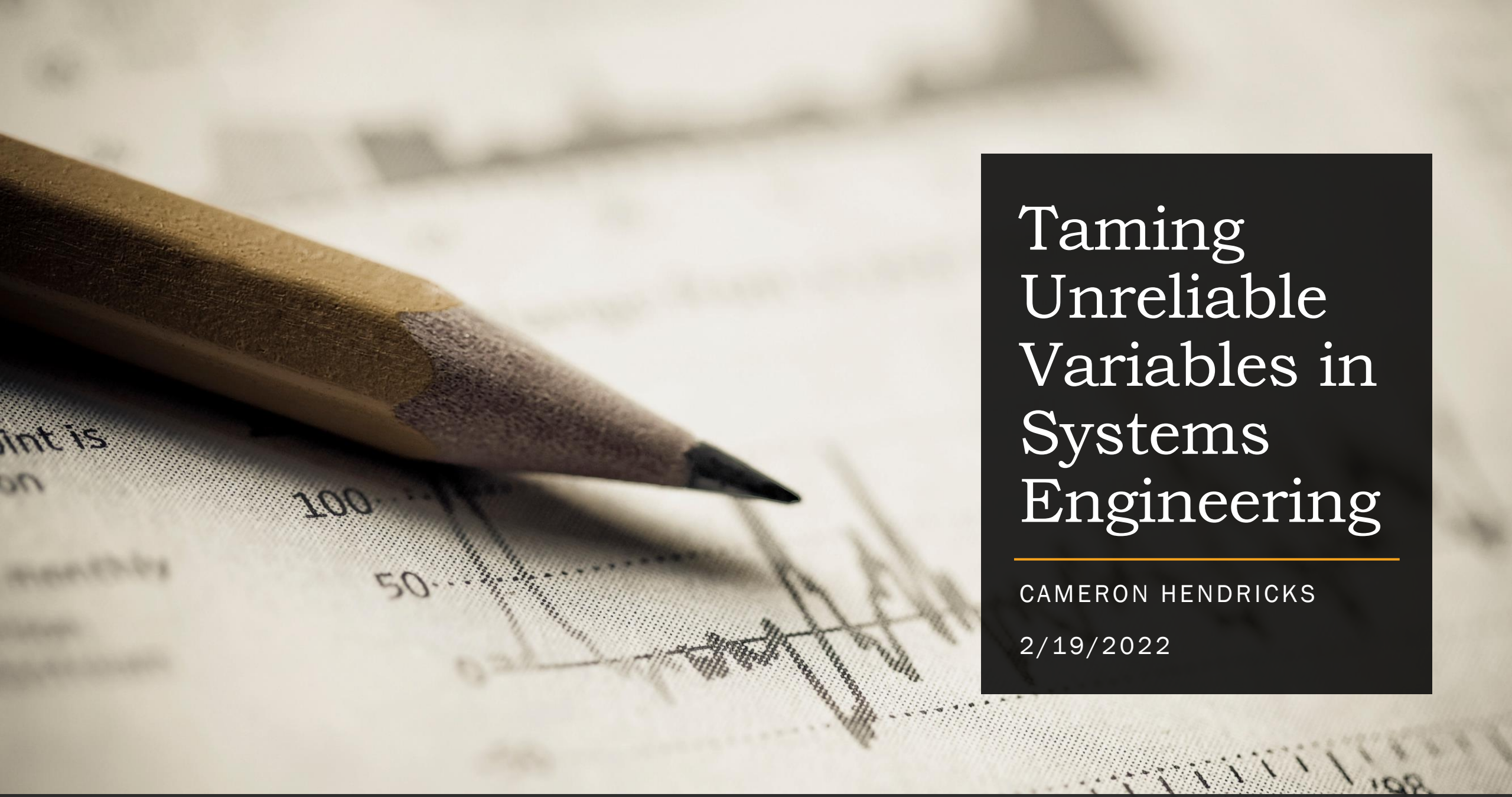

Taming Unreliable Variables in Systems Engineering

CAMERON HENDRICKS

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Introduction

Cameron Hendricks is the Pratt and Whitney Fellow for MBSE

He started his career in 1997 working for Hughes Aircraft, and spent most of his career working government contracts for Raytheon, working with other government contractors such as Lockheed Martin, Boeing, General Dynamics, Northrop Grumman and many other smaller contracts, and has spent a large part of his career analyzing and improving engineering performance

None of the topics covered here are proprietary or reflect any specific problems of any of the above companies

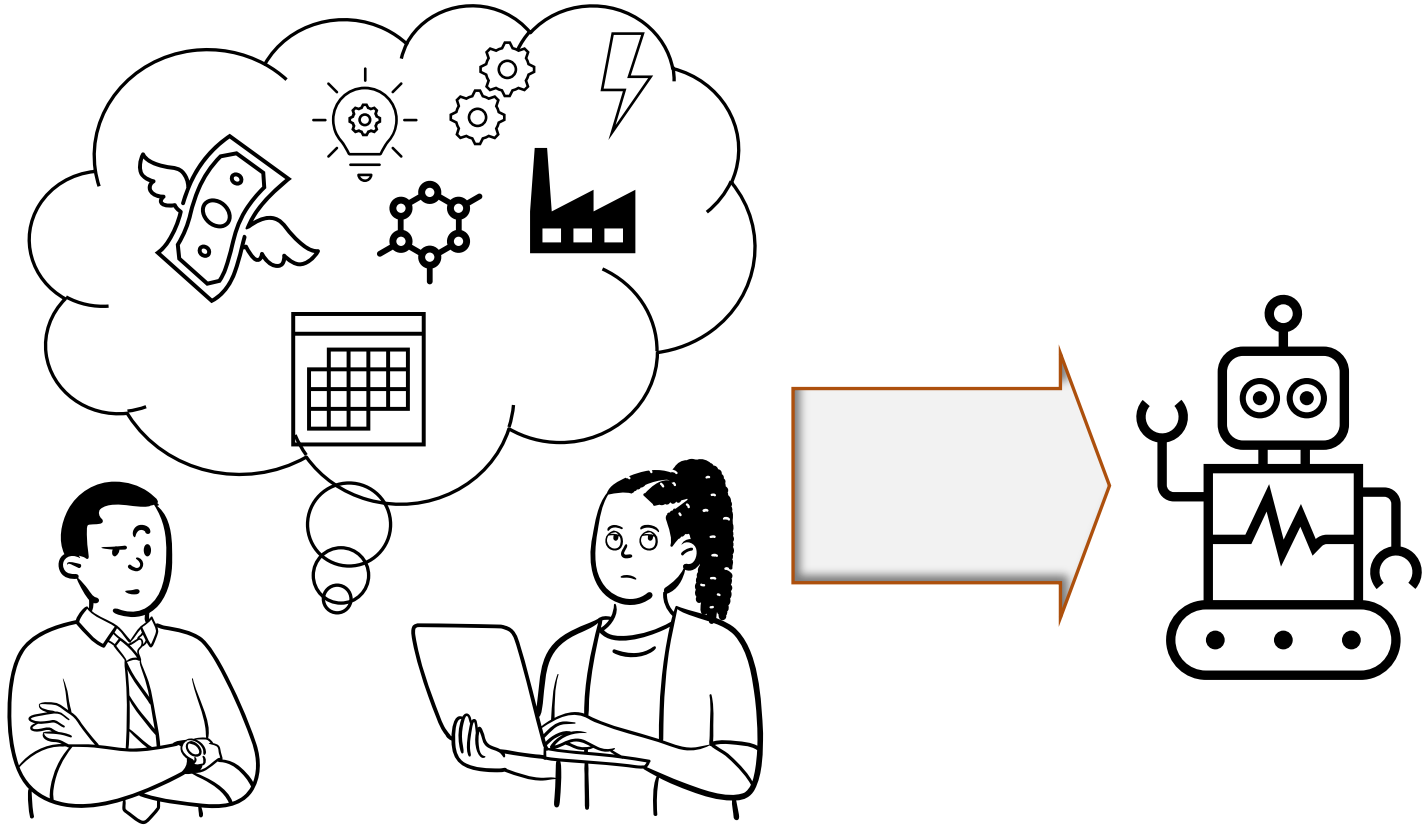
What we think “engineering” is

We often think of the *manager* as someone who is provides time and money to the *engineer* so that the engineer can consume resources to create a product

What “engineering” is

The *manager* is a supplier of constrained resources that are part of the engineering problem, specifically *time* and *money*

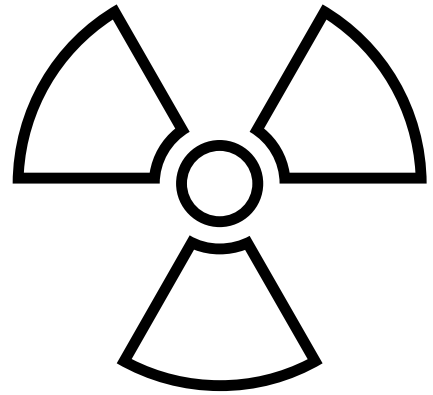
Time and money are always part of the formula when the solution is not already known

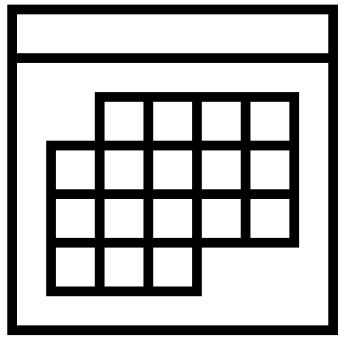


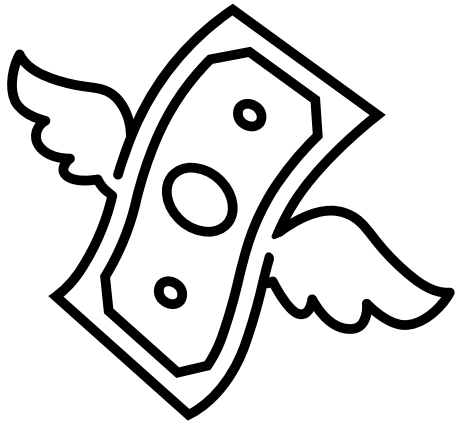
Objectives of today's conversation

We want to be able to explain the basis and methodology of engineering cost estimation to people who are stakeholders so that:

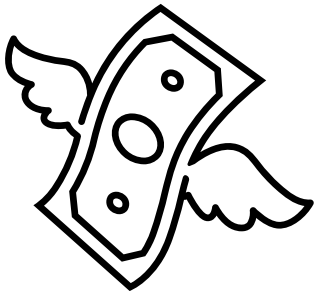
- They can have confidence in our estimates
- We can handle address conflict and business needs in a manner that is ethical to everyone involved







Time, money and risk in the context of engineering

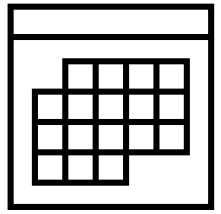


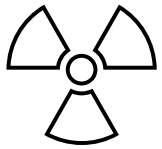
In engineering, *money* is a *substitute variable* for something that has not been acquired

- Sometimes, it can be transformed into known entities - **purchasing**
- Other times, it is transformed into entities that are not yet known - **development**

In engineering, *time* is an estimate of the duration of the transformation of money into material, energy or data

- In **development** the specifics of the material, energy or data is not currently known





Risk is the inverse of the probability that the money can be transformed into the material, energy or data at the planned time

Unreliability == predicting the future

- Stakeholders who understand the estimates can:
  - Assess the level of fidelity of the estimate
  - Take ethical action when there is a conflict between the estimate and the business cost
  - Understand the level of risk associated with a given estimate to consider when creating a plan for an engineering effort which parts are:
    - “safe cost and schedule” associated with purchasing
    - “risked cost and schedule” associated with development

How to predict the future

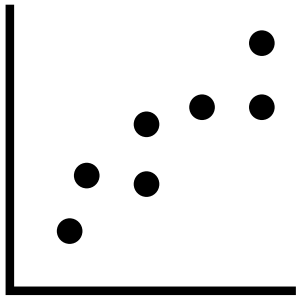
In *engineering* all methods of future prediction involve:

- A ***basis*** – which is an estimate of size of the final material, data and/or energy
- A ***methodology*** – which is a formula to convert estimated basis into time and money

As we transform money into material, data, and energy, we compare actual production against the basis to trend our actual money and time to compare our estimated money and time

- Deltas between the trending actuals and the basis give us the **probability** and **impact** of our risk

Basis == Foundation



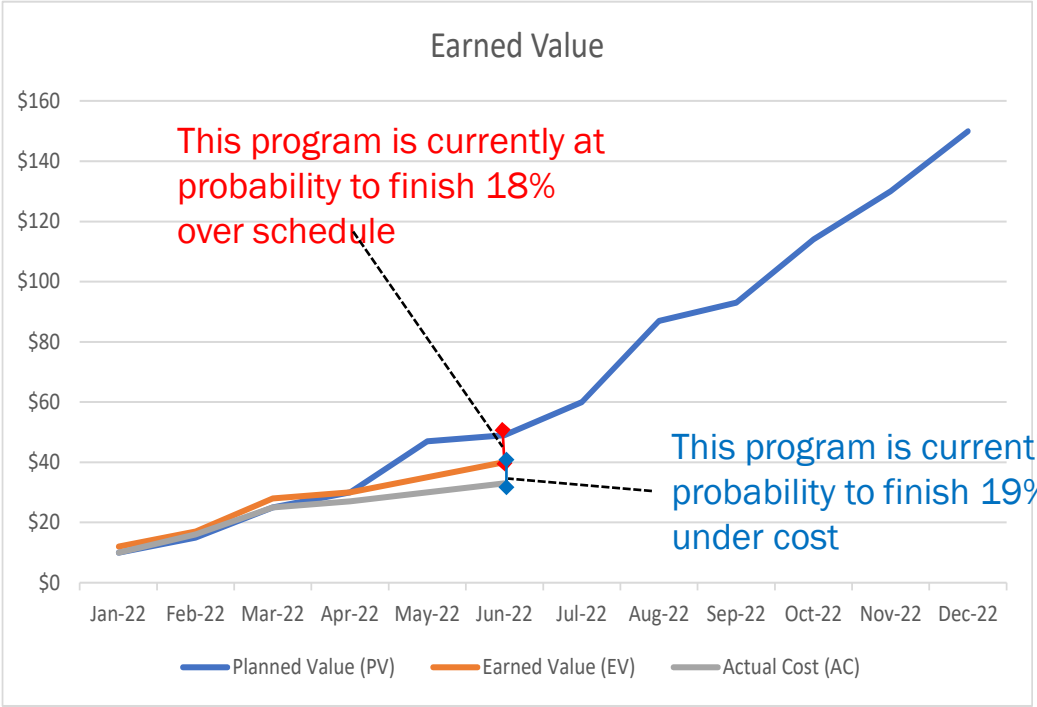
Example – EV to calculate risk

Earned value is a well established and much hated method to track actuals against estimates.

- Cost Variance: CV = EV – AC (what you spent vs what you planned)
- Schedule Variance: SV = EV – PV (how long it took vs what you planned)
- Cost Performance Index: CPI = EV/AC (probability of cost)
- Schedule Performance Index: SPI = EV/PV (probability of schedule)

For more details on EV – see

https://www.pmi.org/learning/library/make-earned-value-work-project-6001



When value is measured in tasks accomplished, it is a “Function based WBS (work breakdown structure). When it is measured in delivered products, it is a “Product based WBS”.

Methods for Predicting Future

Pre-planning strategy

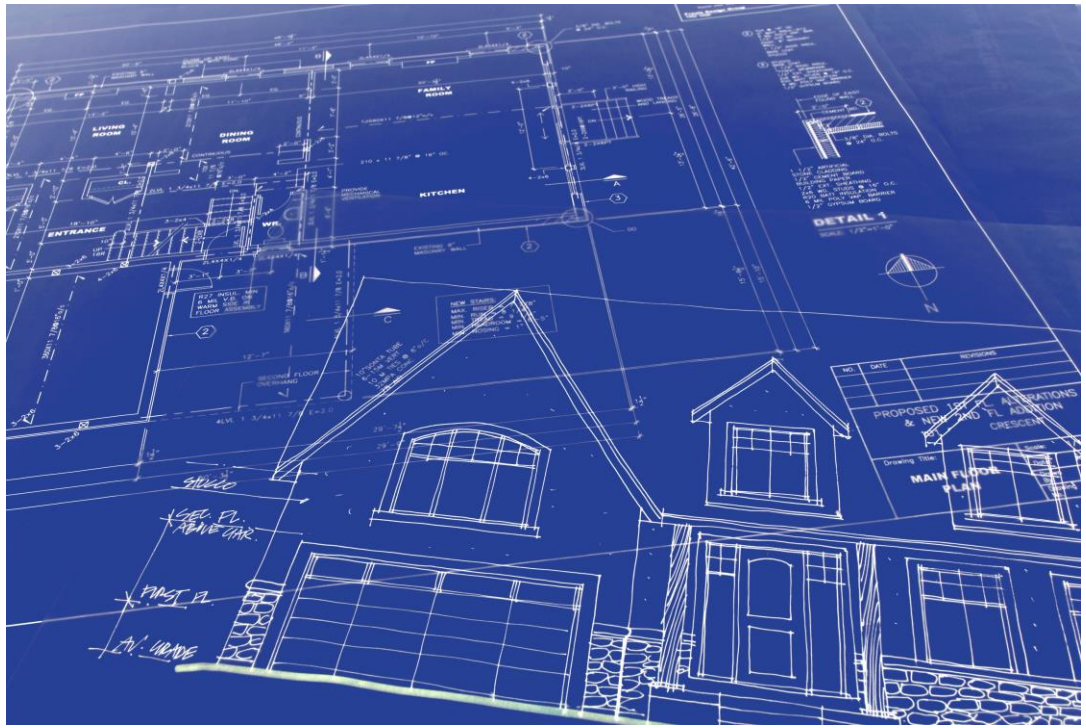
Example: Construction Architecture, Formal PDR and CDR cycle

Basis - Create it virtually (CAD, Simulation)

Methodology - Use the virtual material, energy, data to estimate actual material, energy, data

Pitfalls:

- This methodology estimates cost better than time
- Cost of estimation (virtual creation) is high
- This estimate does not estimate the virtual creation itself



Similarity Estimation

Example: Agile Fibonacci Estimation, also very commonly in BOE estimation in proposals at a large scale

Basis: Use results from projects that are similar

Methodology: Scale the actuals up or down based on "how different" it is

Pitfalls

- The accuracy of this methodology depends on how well you pick the "similar" projects
  - Picking things that sound similar but aren't creates estimates that look accurate but are not
- The accuracy of this methodology decreases as you scale away from your basis (10% change – maybe accurate, 500% change probably not)

= $100

= $125

Parametric Estimation

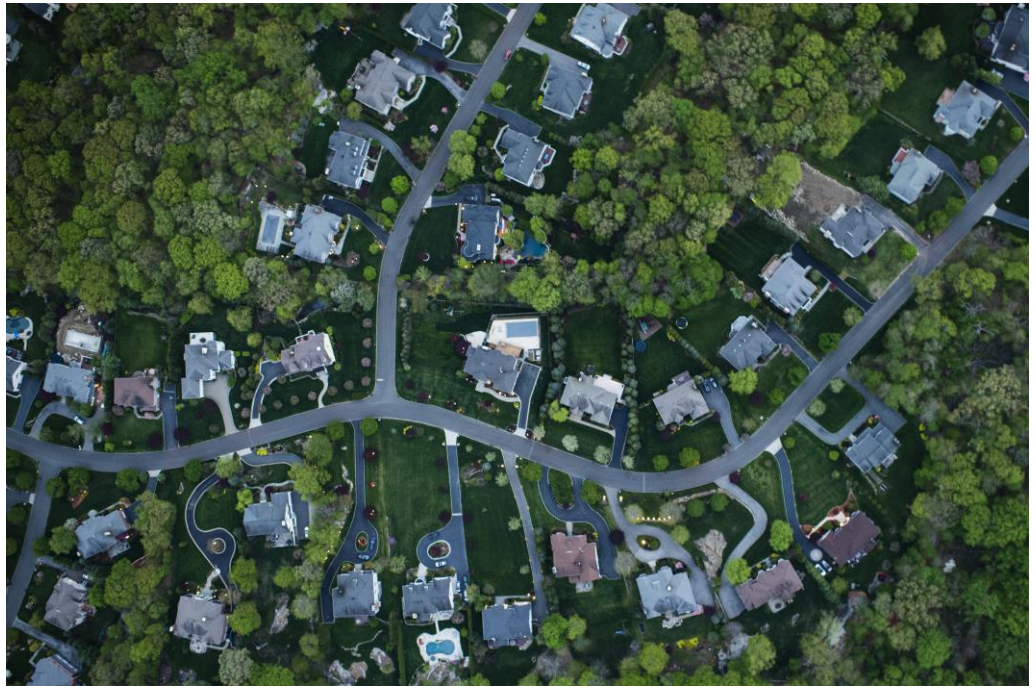
Example: COCYSMO, ESLOC, SEER

Basis: Estimate only specific subset parametric data of the project, use statistical actuals from previous projects for those parts

Methodology: Use a pre-defined parametric formula to calculate cost and schedule based on subset of data

Pitfalls:

- Requires experience estimating parametric data specific to the tool
- Does not produce a plan
- "Engineering Judgement" factors outside of statistical data



A simple example of parametric estimation: estimate square footage of house, multiply by neighborhood cost/square foot. For more detailed explanation of parametric estimation, see https://project-management.info/parametric-estimating/

Wide Band Delphi

Example: Agile User Story Estimation

Basis: Use a common description of the problem and experienced people

Methodology: The people come to a consensus on the estimate informally

Pitfalls:

- Does not scale well when going beyond the scope of a “pizza team”
- Gaps in conversation and experience lead to gaps in estimation

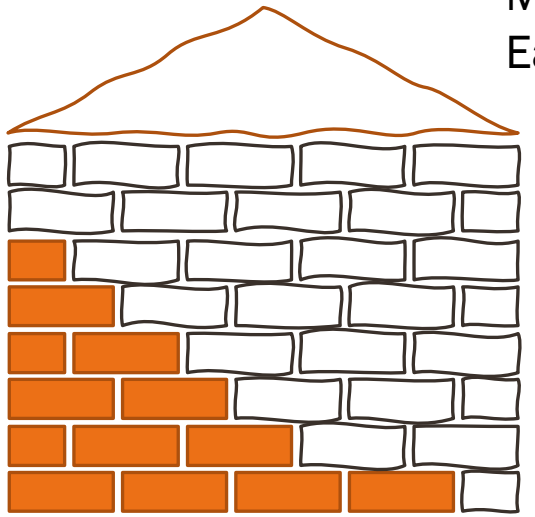
Iterative Development

Basis: Use common outline of the whole scope of work decomposed into small parts, and relative sizing between the parts

Methodology: Project cost and schedule of completed parts onto the whole

Pitfalls:

- Only accurate under condition that the part is fully completed (delivered to customer)
- Often people don't estimate the whole



Example: Agile Backlog Management, Burndowns, Earned Value

How do we handle conflict?

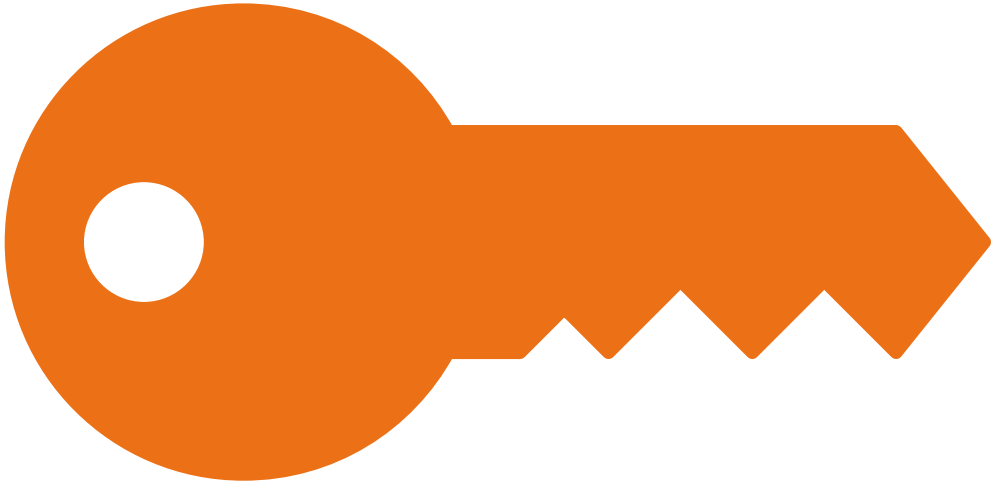
1. Plan on the initial estimate not meeting the business needs
2. Make overt efforts to not make it personal
3. Move on to take the next step to determine together what action to take

It is reasonable and ethical to:

- Alter the scope of the system being bid to find a better business solution
- Ask estimating engineers to double check their work
- Ask estimating engineers to find more basis information to refine the estimate, or to validate the estimate using multiple methodologies
- Fund de-risking efforts to perform some of the work in order to gather more data to refine the estimates
- Create a risky plan (where the cost and schedule don't line up with the estimate), with the consent of the person accountable for the plan
- Make unintentional mistakes in estimating

It is unethical (and in some cases illegal) to:

- Alter the basis or methodology to force the numbers to match a pre-determined amount
- Close out the estimating process because you achieved a known bad result that lines up with the business need
- Solicit less qualified estimators to get a "better bid"



Key success points for all

Copious and accessible data increase ability to estimate

Keep “estimate” and “budget” as independent variables

Keep “Cost, Schedule, and Technical” as dependent variables

Automate tracking tools and estimation formulas

No such thing as “not my problem”

Thank you!

Questions!

Comments!

Entertaining Stories!