# Integration of NASA Cost Tools to Estimate Mission Concept Costs

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# Agenda

Review Customer needs for early concept mission cost estimates

High- Level Overview of Example Mission

Building the estimate- integrating a wide array of Agency tools

How do we return a single informative estimate to the customer?

# What does an Estimate Look Like for Pre-Phase A Missions?

Goal: Determine feasibility of designed mission to fall into specified cost range

Challenge: Mission concepts can be drastically different than anything that has previously flown

Target Deliverable: A single Cost Cumulative Distribution function (S-curve) that encompasses the entire mission, including key assumptions

- Some lower-level cost results; generally down to subsystem and *major* components → at this stage, high-level info is most reliable

Available Data:

- Master Equipment List (MEL)- masses, power levels, Technology Readiness Levels (TRLs), dimensions, design engineer’s notes
- Concept of Mission Operations (Con-ops)
- Intended fault tolerance and risk posture
- Access to key team members (subsystem leads)

# Let’s walk through the process with an example mission!

Pre-phase A Mission Design

Designed by Compass, concurrent engineering team at NASA GRC

Orbiter and 6 landers use a 5-month trajectory to Venus and carry out primary science operations

Estimate Scope: Lifecycle (Phase A-E) Cost Estimate

# What does the mission look like from a cost estimator's perspective?

Four Unique hardware elements:

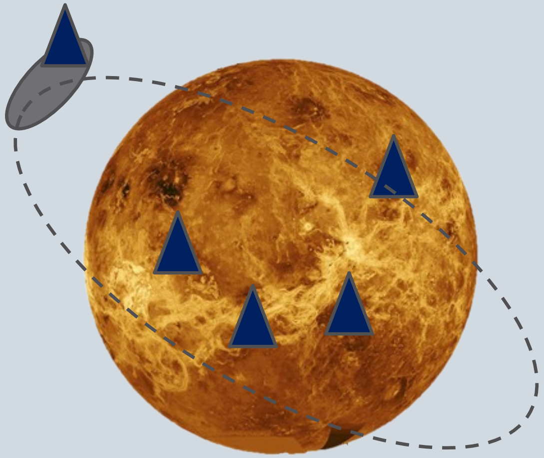
- Orbiter
- Landers
- Entry, Descent and Landing System (EDL)
- Science Package

Software Costs

Element-Level Integration Costs (System Wraps)

Mission-Level Integration Costs (Mission Wraps)

Phase E mission operations and science costs



# What tools are at our disposal to address each of these elements?

Library of Cost Estimating Relationships (CERs) based on CADRe data developed by GRC Cost and Economic Analysis Office (CEAO)

Commercial estimating software PRICE TruePlanning and SEER-H

NASA Instrument Cost Model (NICM)

NASA Analogy Software Costing Tool (ASCoT)

Mission Operations Cost Estimating Tool (MOCET)

ONE NASA COST ENGINEERING DATABASE

# How Do We Decide Which Tools to Use?

Pre-Phase A, expect estimates with wide uncertainty ranges

- COTS tools are useful where no historical data is available, but have less internal visibility
- Using in-house developed CERs → better understanding of data set, its applicability, and the limitation of each CER

Review GRC CER library for those applicable to the mission being estimated

- Cognizant to ensure mass (and any other relevant input parameter) of the element being estimated is within the range of data used in CER development

Most CERs that have been developed in-house are spacecraft hardware based

- GRC Developed CERs: C&DH S/S, Thermal S/S, Structures S/S, etc…
- Software, Instruments, and Phase E mission operations all fall outside scope of CERs

# Which Tools should we use in the Venus Mission?

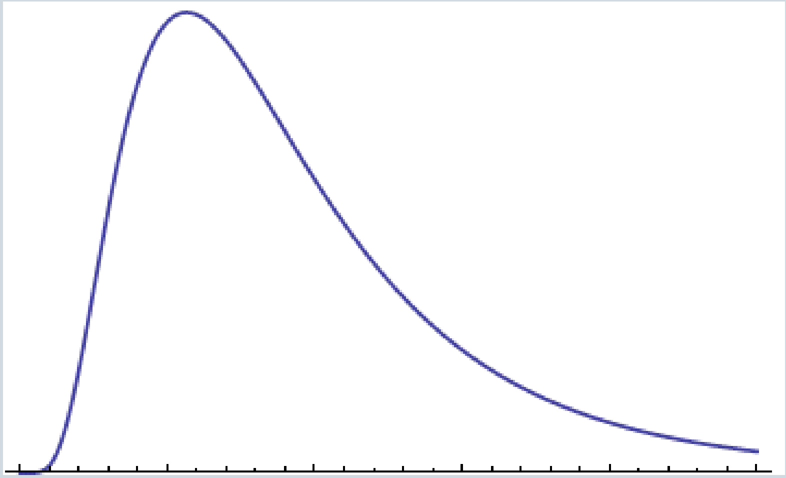
| Element | Estimating Tool |
|---|---|
| Orbiter | GRC Developed CERs |
| Lander, EDL | TruePlanning |
| Science Package | NICM |
| Software | ASCoT |
| Mission-Level Wraps | GRC Developed CERs |
| Phase E Operations | MOCET |

# Integrating Various Estimates into a Single Model

Excel-based model (Phase A-E)

Use Crystal Ball to run Monte-Carlo simulations

- Assume estimate from each cost tool is mode of Lognormal Distribution[1]
- Where possible, hardware costs are split to recurring and non-recurring allowing smooth handling of multiple quantities. Engineering judgment can be used when data is unavailable
- Model Uncertainty:
  1. Mass
  2. Development Cost
  3. Flight Hardware Cost

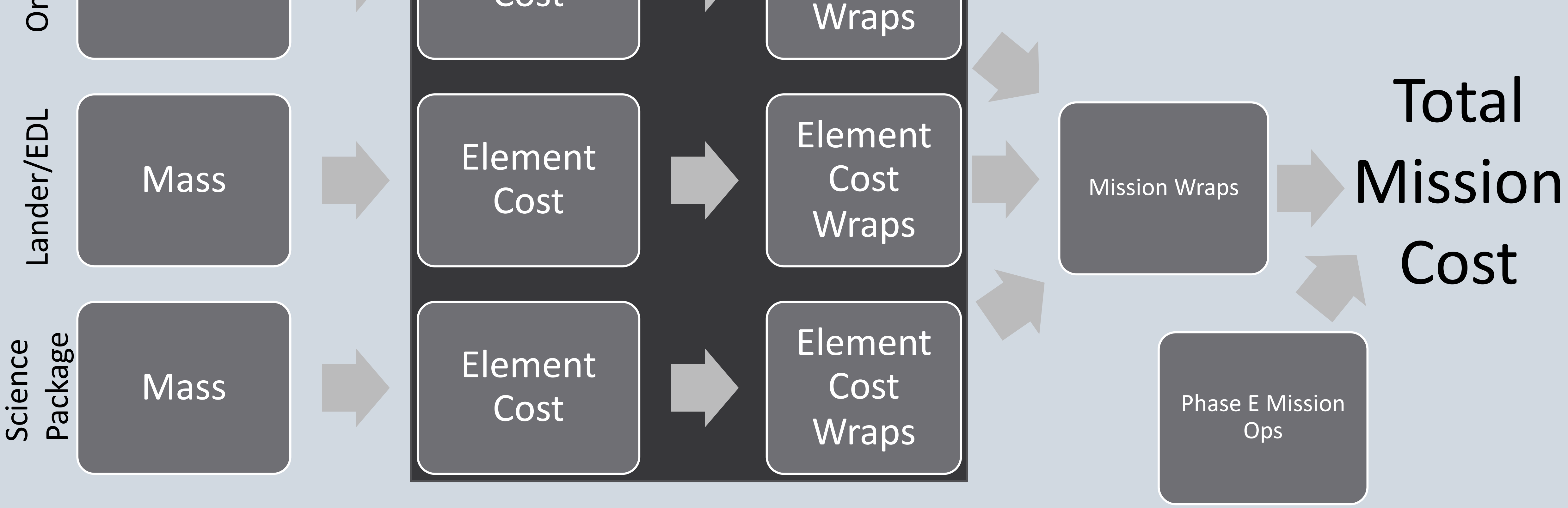


1- “What’s the Point”, Turnbull et al, 2015 NASA Cost Symposium

| Estimating Tool | Model Integration Approach |
|---|---|
| GRC Developed CERs | • For each element, mass from the MEL is linked to applicable CER<br>• Triangular Distribution applied to input Masses<br>• Using CER regression statistics, Excel model assumes Lognormal (calculated mean and standard deviation) |
| TruePlanning | • Review TruePlanning estimate<br>• If necessary, assume a Standard Error based on assessment of system and relative applicability of TruePlanning<br>• Excel model applies Lognormal assumption defined by calculated mean and standard deviation |
| NICM | • Review NICM estimate<br>• If necessary, assume a Standard Error based on assessment of instrument and relative applicability of NICM CER<br>• Use Standard Error to calculate Standard Deviation |
| ASCoT | • Review ASCoT estimate<br>• Work Month output from ASCoT -> assume triangular distribution<br>• Apply standard Monthly Rate to yield software costs |
| MOCET | • Review MOCET estimate<br>• Assume a Standard Error based on assessment of system and relative applicability of MOCET<br>• Excel model applies Lognormal assumption defined by calculated mean and standard deviation |

Applied a uniform correlation to all pairs of random variables to offset the unknown correlation between each

*If necessary, Standard Error Assumption is subjective and can fall anywhere from 20% to 100% depending on the applicability of tool to the design*

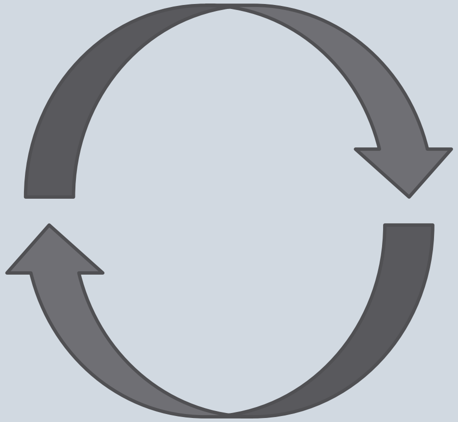

Orbiter
Lander/EDL
Science Package
Mass
Mass
Mass
Element Cost
Element Cost
Element Cost
Element Cost Wraps
Element Cost Wraps
Element Cost Wraps
Mission Wraps
Phase E Mission Ops
Total Mission Cost

# We have a working model- Do the results make sense?

Review Coefficient of Variation ($\frac{Mean}{Standard\ Deviation}$)

This is a subjective assessment: general rule of thumb is around 0.4 with variation expected according to design novelty

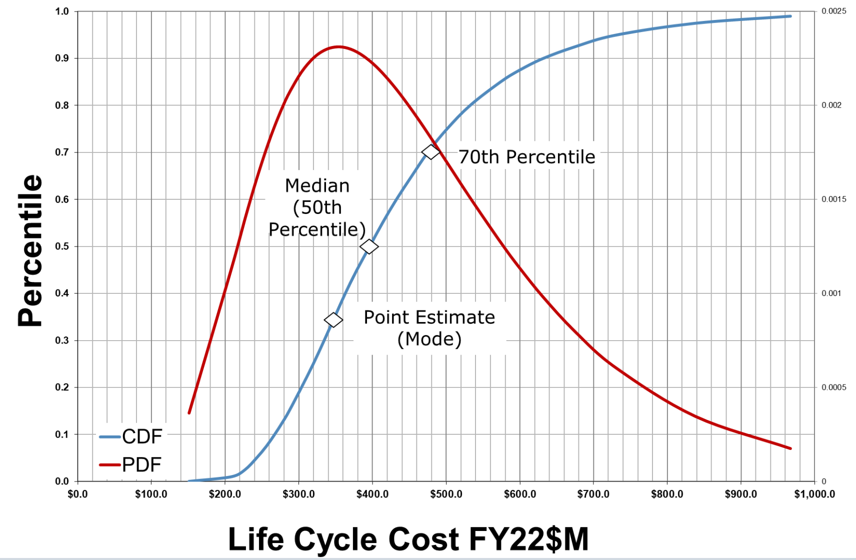
If CV does not align with design novelty, re-evaluate inputs and iterate



# NOW we have preliminary estimates- how do we present it to the customer?

S-curve (CDF) of resulting distribution

- Can pull out any point values customer wants to see- usually mode, 50th and 70th




| Example Mission Cost Summary FY21$M | Phase A-D | Phase E | Total |
|---|---|---|---|
| Phase A | 10 | | 10 |
| Phase B/C/D/E Costs | 622 | 70 | 692 |
| 1 Program Management | 30 | | 30 |
| 2 Systems Engineering | 40 | | 40 |
| 3 Safety & Mission Assurance | 15 | | 15 |
| 4 Science | 20 | | 20 |
| 5 Payload | 80 | | 80 |
| 6 Flight System | 375 | | 375 |
| 7 Mission Operations | 15 | 70 | 85 |
| 8 Launch Vehicle/Services | - | | - |
| 9 Ground System | 15 | | 15 |
| 10 Systems Integration & Testing | 30 | | 30 |
| 11 Education & Public Outreach | 2 | | 2 |
| **Total Mission Cost** | **632** | **70** | **702** |

Pick a value to give as point estimate (typically provide mode)

- Use ratio of deterministic output to point estimate as a factor to approximate subsystem and component-level values of the point estimate

# Take-Aways

GRC utilizes a diverse set of tools to apply to the various elements of a conceptual mission

- Over the past year, this approach has been used to estimate numerous mission designs including: a lunar fission power system, an earth orbiting cryogenic fuel transfer demonstration, Mars orbiters and Venus orbiters

Account for the relatively high degree of uncertainty in early-stage mission design cost estimates

Subjective engineering judgment needs to be applied to assess and apply uncertainty for a given element or mission in early designs

# References

Venus Image: https://www.nasa.gov/press-release/nasa-selects-2-missions-to-study-lost-habitable-world-of-venus

What's the Point?: https://www.nasa.gov/sites/default/files/files/22_Whats_the_Point_GRC_submission_2_tagged.pdf