NASA Cost Estimating

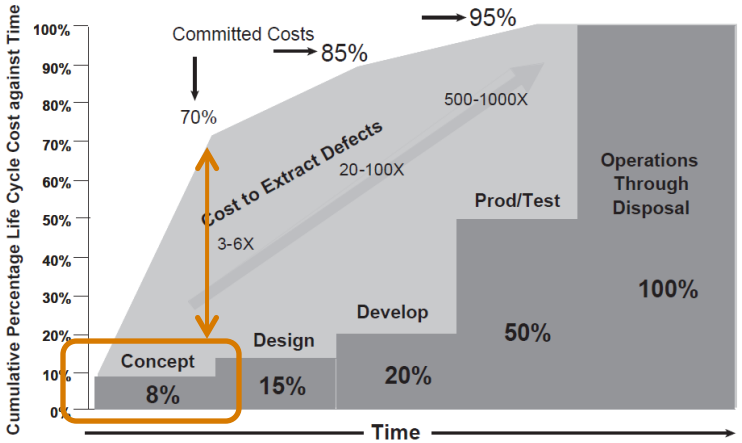
Jordan Klovstad
Space Mission Analysis Branch
jordan.j.klovstad@nasa.gov
NASA Langley Research Center
Hampton, Virginia

Background to our Perspective

Conceptual Design – synonymous to concept studies, feasibility studies, pre-formulation work, Pre-Phase A

Purpose of Pre-Phase A/Concept Studies as defined in NASA Systems Engineering Handbook (2007)

"To produce a broad spectrum of ideas and alternatives for missions from which new programs/projects can be selected. Determine feasibility of a desired system, develop mission concepts, draft system-level requirements, identify potential technology needs."



Source – INCOSE Handbook, cited from Defense Acquisition University , 1993

Cost and Affordability within Conceptual Design

<u>End Usage of Results</u>

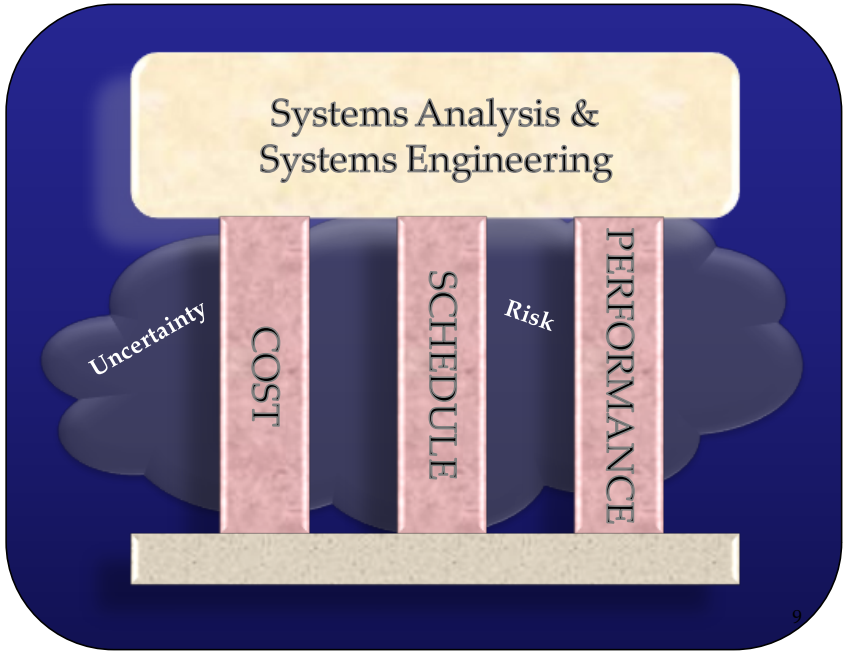
- Concept Screening – e.g., trimming the trade tree
- Feasibility – e.g., could this concept 'close'

<u>Estimating Level</u>

- Top level system characteristics
- Major subsystem characteristics

<u>Estimating Methodology</u>

- Multi-attribute parametric CERs
- Probabilistic treatment of assumptions where warranted



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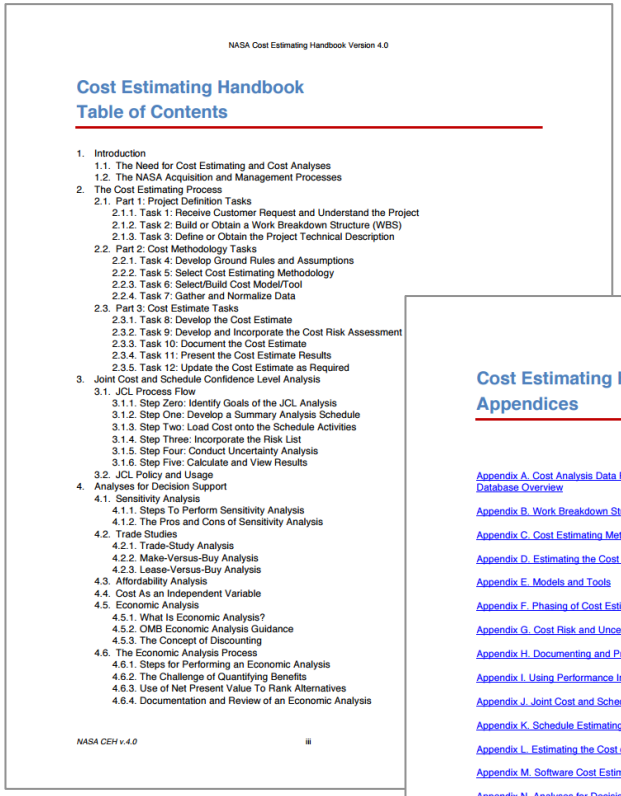

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Cost Estimating Handbook
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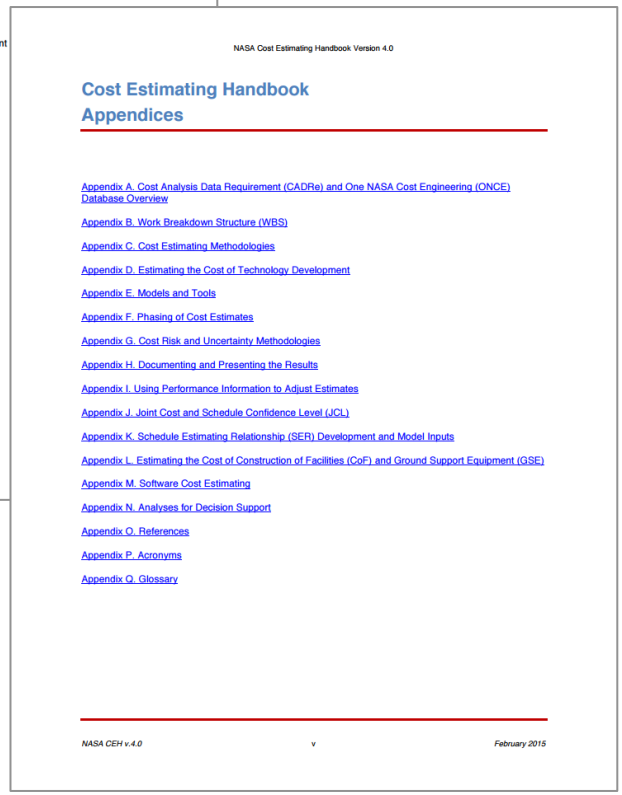

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Cost Estimating Process

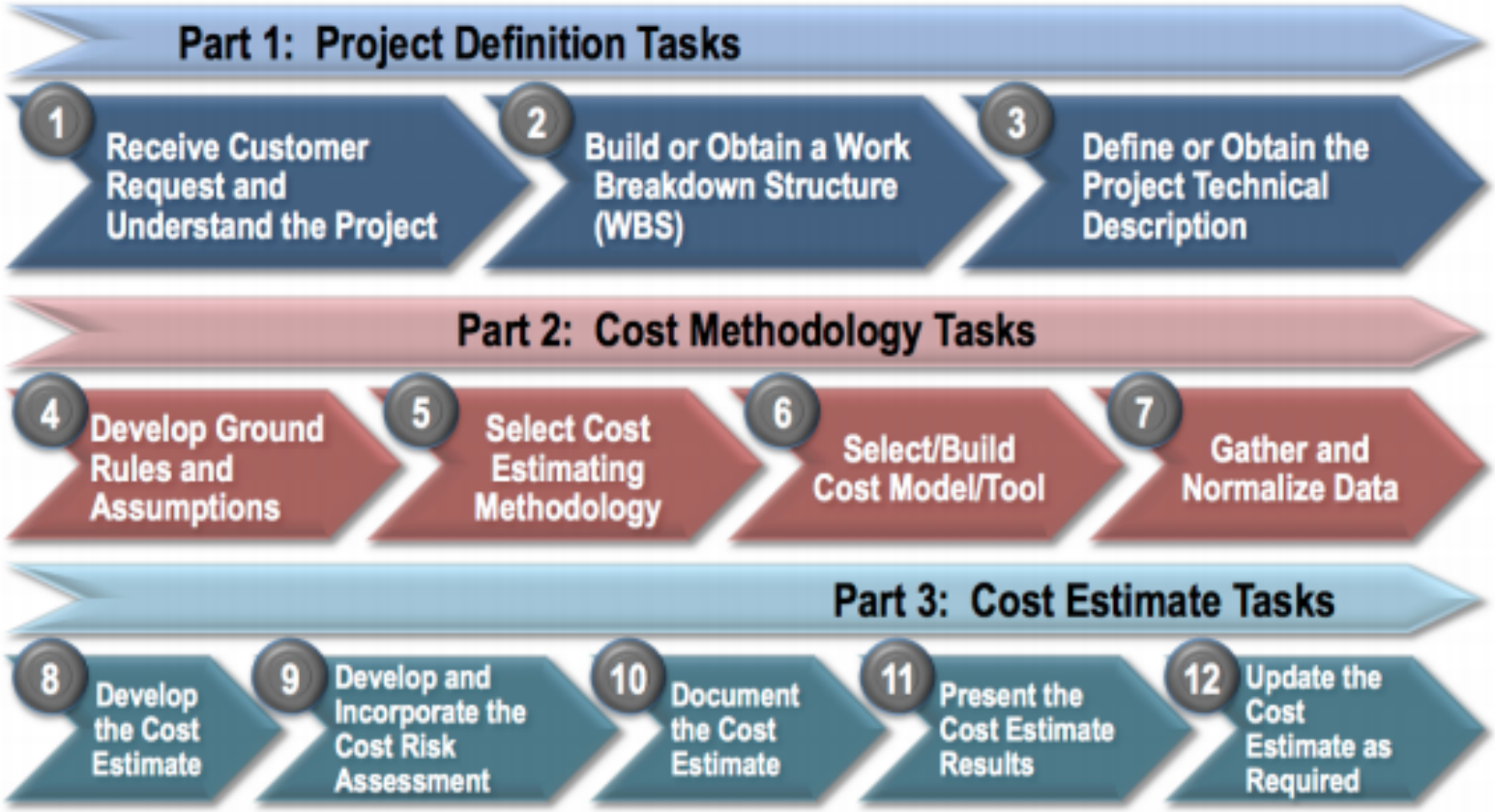

Figure 2. The NASA Cost Estimating Process

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NASA Project Life Cycle

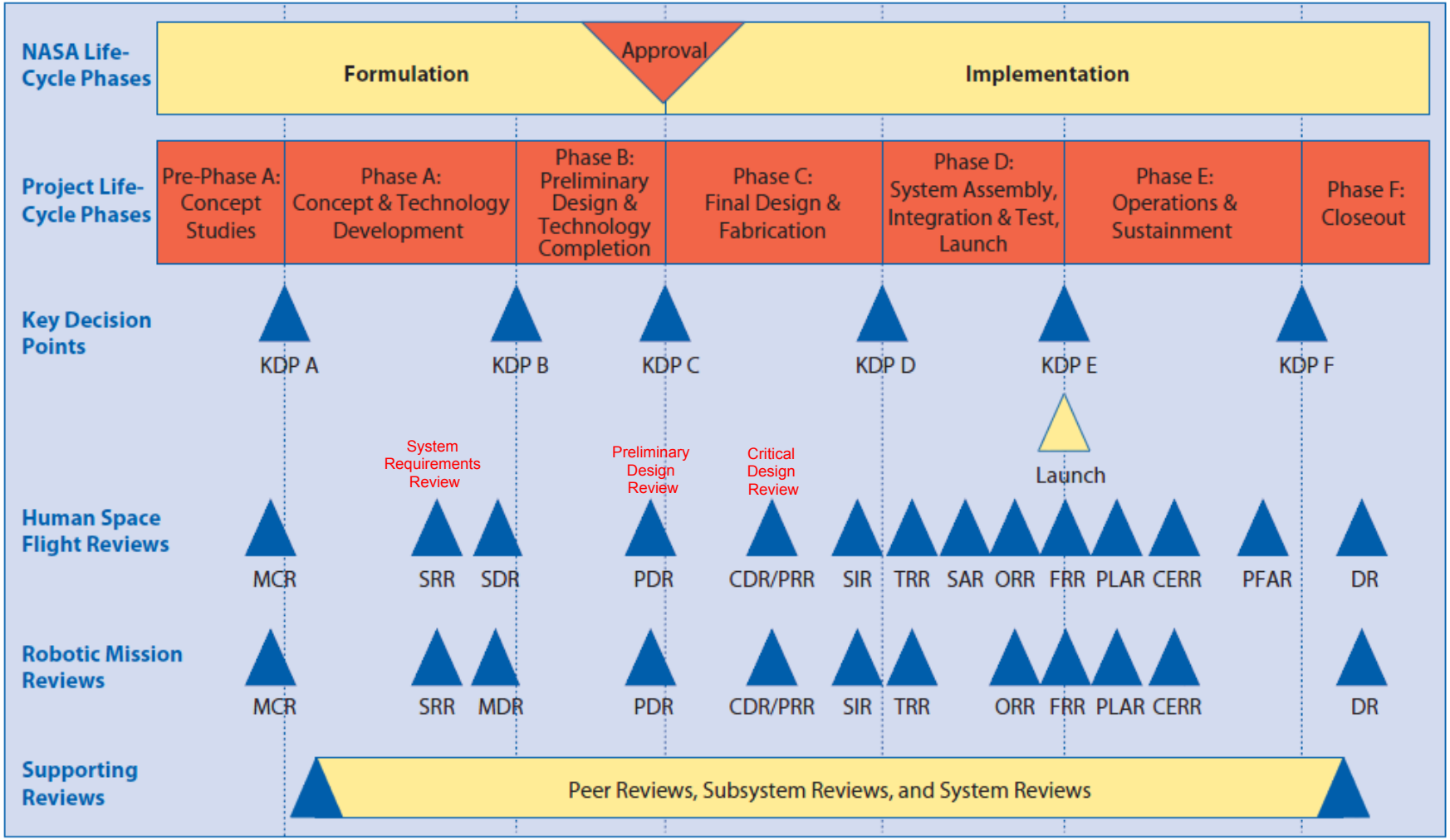


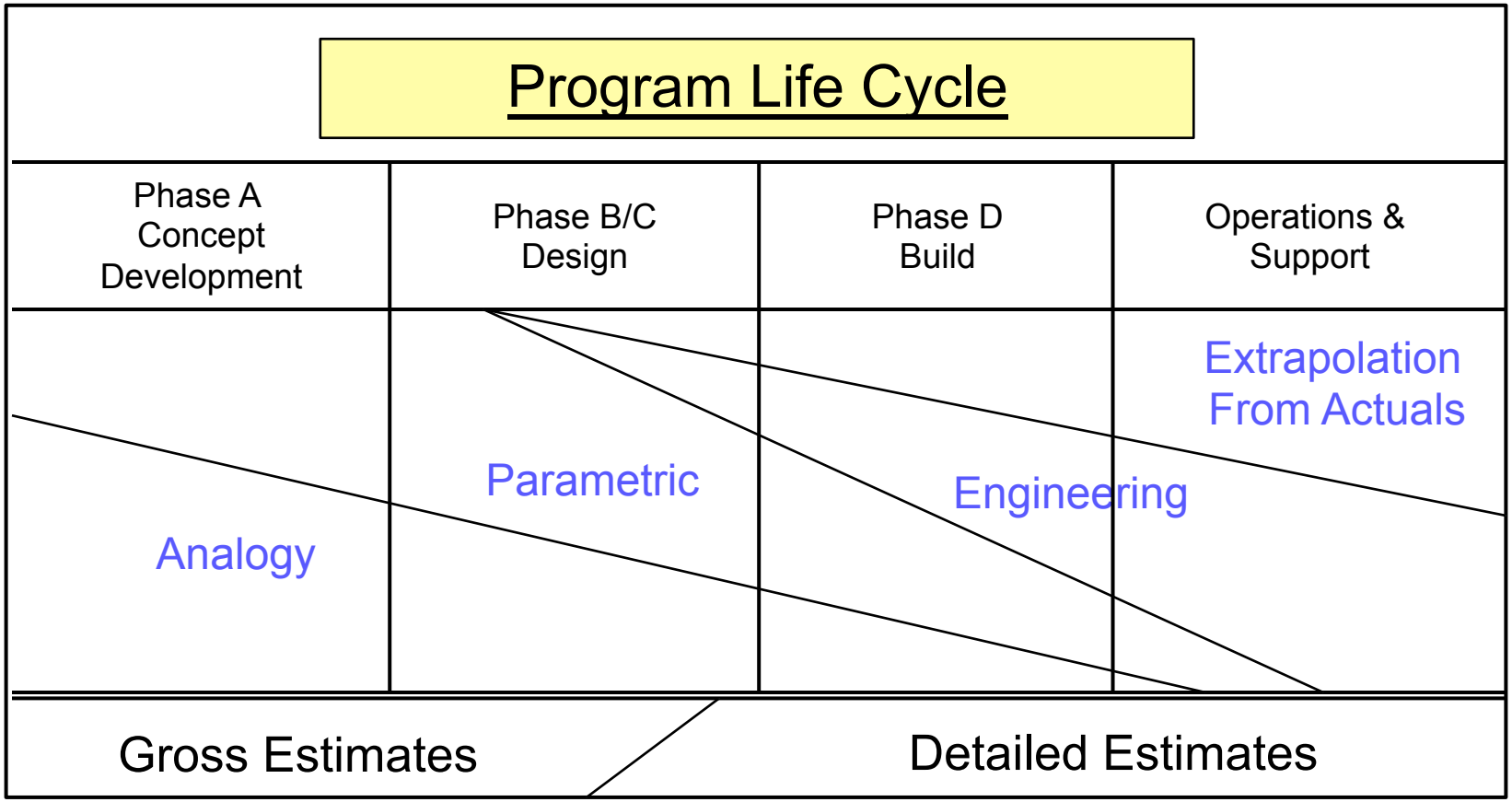
Figure 3.0-2 NASA project life cycle

Key Acronyms:

- KDP – Key Decision Point
- SRR – Systems Requirements Review
- PDR – Preliminary Design Review
- CDR – Critical Design Review

http://www.acq.osd.mil/se/docs/NASA-SP-2007-6105-Rev-1-Final-31Dec2007.pdf

Methodology Comparison



Use of Cost Estimating Methodologies by Phase

http://www.nasa.gov/sites/default/files/files/01_CEH_Main_Body_02_27_15.pdf

Methodology Comparison

Table 1-7. Strengths and Weaknesses of Analogy Method of Cost Estimating

Strengths	Weaknesses
Based on actual historical data	Relies on single data point
Quick	Can be difficult to identify appropriate analog
Readily understood	Requires "normalization" to ensure accuracy
Accurate for minor deviations from the analog	Relies on extrapolation and/or expert judgment for "adjustment factors"

Table 1-6. Strengths and Weaknesses of Parametric/CER Cost Methodology

Strengths	Weaknesses
Once developed, CERs are an excellent tool to answer many "what if" questions rapidly	Often difficult for others to understand the relationships
Statistically sound predictors that provide information about the estimator's confidence of their predictive ability	Must fully describe and document selection of raw data, adjustments to data, development of equations, statistical findings and conclusions for validation and acceptance
Eliminates reliance on opinion through the use of actual observations	Collecting appropriate data and generating statistically correct CERs is typically difficult, time consuming, and expensive
Defensibility rests on logical correlation, thorough and disciplined research, defensible data, and scientific method	Loses predictive ability/credibility outside its relevant data range

http://www.nasa.gov/pdf/263676main_2008-NASA-Cost-Handbook-FINAL_v6.pdf

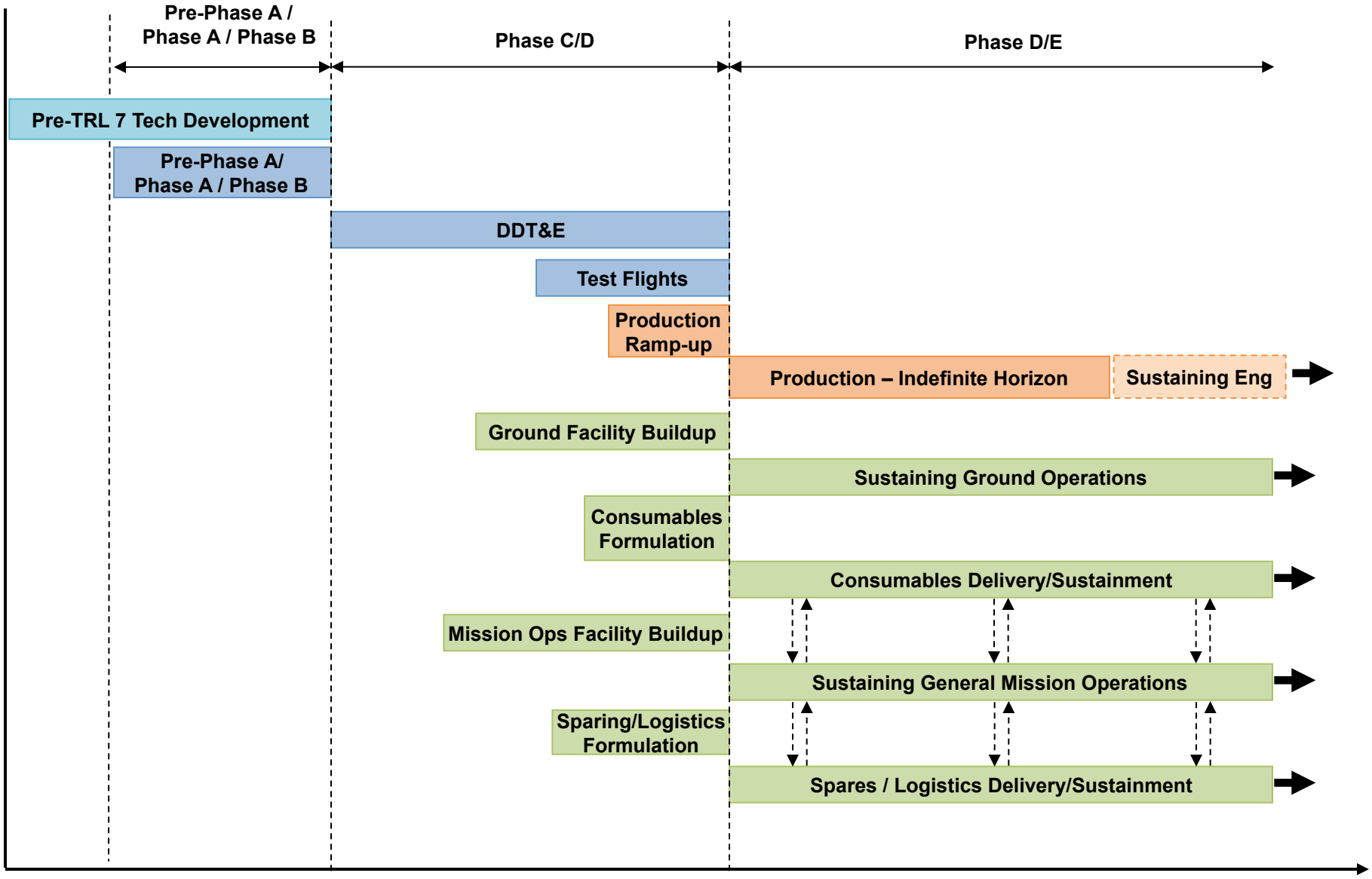
Methodology Comparison

Table 1-8. Strengths and Weaknesses of Engineering Build Up Method of Cost Estimating

Strengths	Weaknesses
Intuitive	Costly; significant effort (time and money) required to create a build-up estimate
Defensible	Not readily responsive to "what if" requirements
Credibility provided by visibility into the BOE for each cost element	New estimates must be "built-up" for each alternative scenario
Severable; the entire estimate is not compromised by the miscalculation of an individual cost element	Cannot provide "statistical" confidence level
Provides excellent insight into major cost contributors	Does not provide good insight into cost drivers
Reuse; easily transferable for use and insight into individual project budgets and individual performer schedules	Relationships/links among cost elements must be "programmed" by the analyst

http://www.nasa.gov/pdf/263676main_2008-NASA-Cost-Handbook-FINAL_v6.pdf

Types of Cost for Single System



Commonly Used Tools (hardware)

- **Project Cost Estimating Capability (instructions for access on RASC-AL website)**
  - Formerly NAFCOM (NASA / Air Force Cost Model)
  - Government tool developed by Victory Solutions/MSFC
  - Subsystem-level parametric analysis
  - Intended to be one-stop shop for cost and schedule estimating capability
  - Includes cost-risk and some schedule estimating capability
  - Heritage is launch vehicles and space systems, contains embedded liquid rocket engine CERs

- **SEER-H**
  - Developed by Galorath
  - Subsystem and component-level parametric analysis
  - Includes cost-risk and schedule estimating capability
  - Heritage is numerous complex systems, including but not limited to aerospace

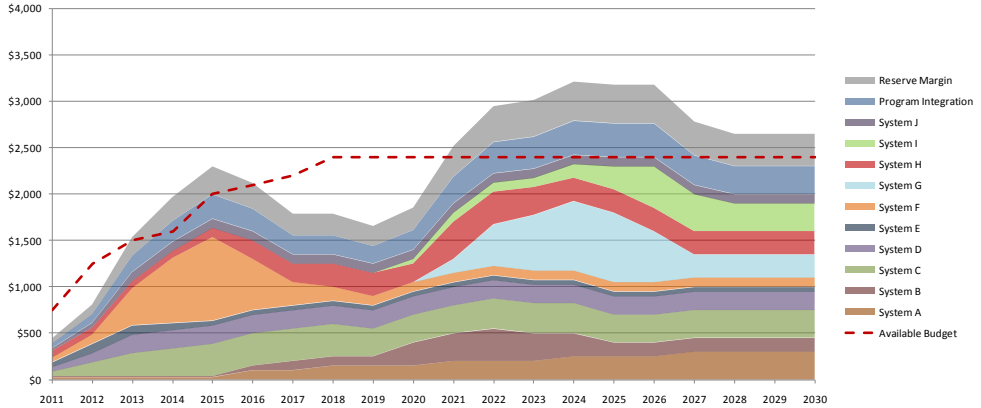
- **PRICE-H**
  - Developed by PRICE Systems
  - Subsystem and component-level parametric analysis
  - Includes cost-risk and schedule estimating capability
  - Heritage is numerous complex systems, including but not limited to aerospace

Affordability Integration

- **Different than cost estimating**
  - Often multiple systems
  - Includes comparison to available budgets
  - Takes into account cost phasing assumptions, learning curves, and inflation
  - Opens trade space temporally

- **Most tools do not provide significant affordability integration support**
  - Most focus on single systems
  - Commonly performed in MS Excel

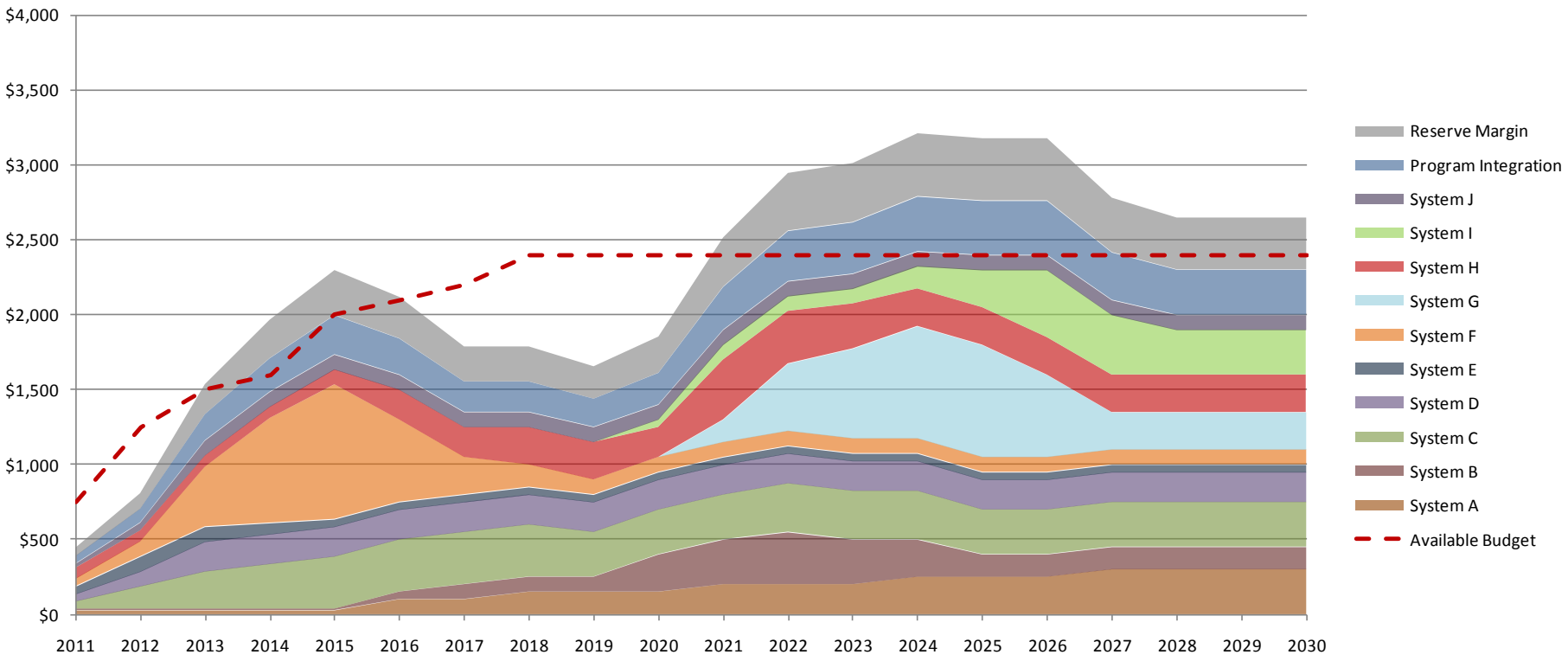
- **Common Product**
  - "Sandcharts" – time-phased visualization of annual sum of costs compared to budgets



Is a Picture Always Worth a Thousand Words?

1. Is this architecture "affordable"?
2. Which system is the most expensive?
3. Which system presents the biggest challenge?
4. What key assumptions are missing?

Below is a commonly used 'sandchart' plot that we have routinely found our customers expect to see



Common Oversights (1 of 2)

- **Technology development ramifications not included**
  - Advanced technology development costs can be considerable, and should be phased before development

- **Wraps, fees, and reserves not always accounted for**
  - Wraps capture government oversight costs and other general & administrative costs (~15%)
  - Fees capture prime contractor profit (~%10)
  - Reserves represent margin (simplistic assumption is commonly ~25%)

- **Inflation not properly accounted for (NASA inflation index available at https://www.nasa.gov/offices/ooe/CAD/Publications.html)**

- **Cost models assumed to be perfect answer**
  - At best analysts can quantify various types of uncertainty using statistical confidence levels
  - At a minimum analysts should consider providing a low and high bounding of results
    - And be able to provide explanation as to what risks or uncertainties cause the potential range

- **Insufficient documentation**
  - All pertinent assumptions should be documented at some level
  - High-level presentation should include subset of assumptions that make a difference
  - Challenge is finding the appropriate balance between up-front assumptions and backup material

Common Oversights (2 of 2)

- **Fixed versus variable/marginal costs**
  - In reality some portion of cost in a given year is fixed in nature (e.g., non-flight rate dependent)
  - Major consideration for systems with higher production rates

- **Software costs are not accounted for**
  - Software development is a significant cost for some systems due to increase complexity, lines of code, etc.
  - Already accounted for within Avionics costs for smaller bus/instrument missions
  - Not fully accounted for within complex manned systems

Questions?

- **In an April 2011 document, NASA reported that NAFCOM estimated the cost of Falcon 9 development, if done by NASA, at $1.3B (cost plus fee). In comparison, estimates using SpaceX procedures and costing inputs, resulted in a cost of $440M (firm fixed price). To what extent can we assume the Mars settlement program will take advantages of modern "Silicon Valley" development processes, or do we need to assume it will be done by NASA using traditional NASA processes? (reworded)**
  - This observation certainly aligns with how things work inside vs. outside large government entities
  - To assume NASA magically goes away and everything is developed by SpaceX will not be embraced by NASA (surprise!)
  - Assuming NASA can operate as efficiently as SpaceX is also unrealistic
  - Hopefully NASA can learn from private companies like SpaceX and the answer will fall somewhere in the middle