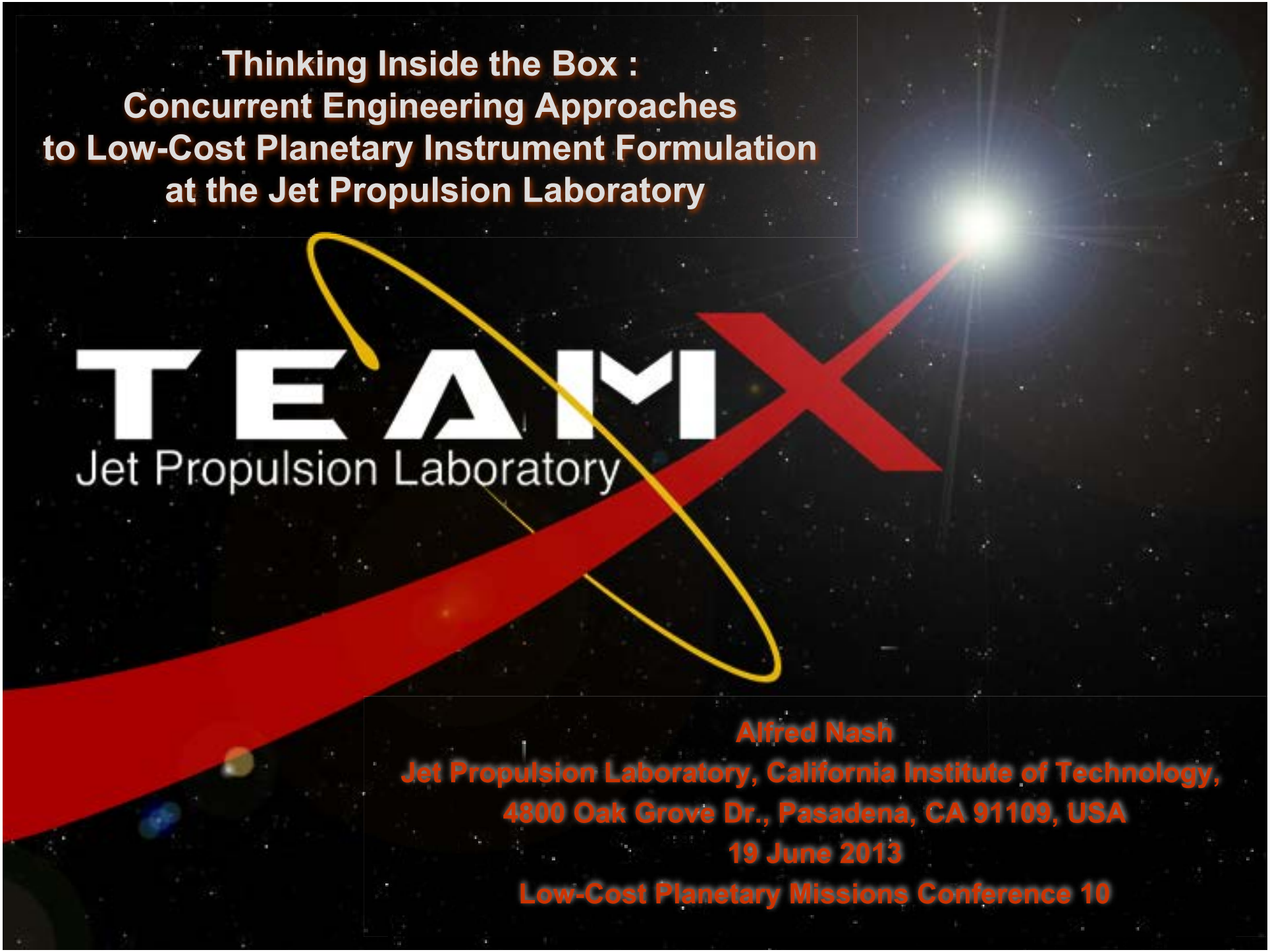
# Thinking Inside the Box : Concurrent Engineering Approaches to Low-Cost Planetary Instrument Formulation at the Jet Propulsion Laboratory

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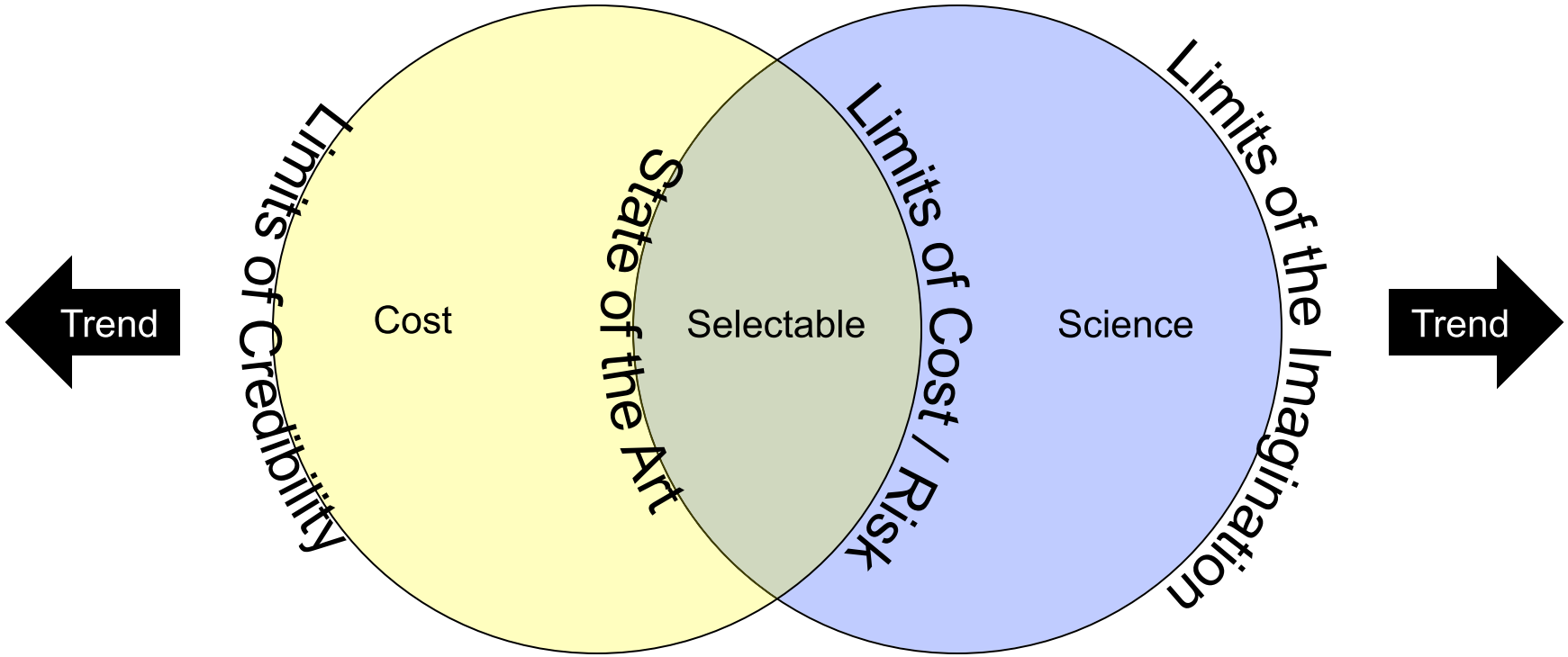
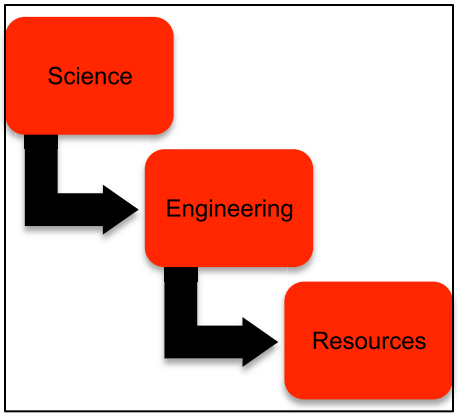
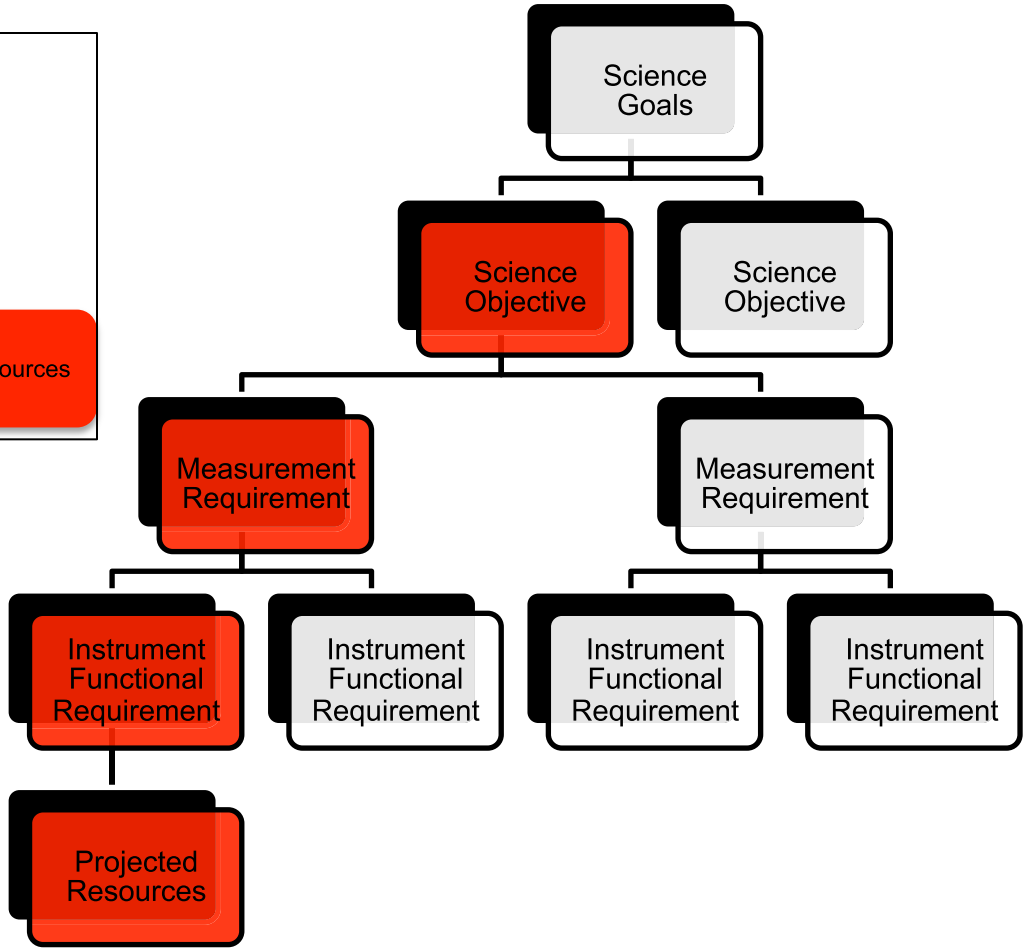
# The Low Cost Planetary Mission Challenge: Navigating Between Scylla and Charybdis



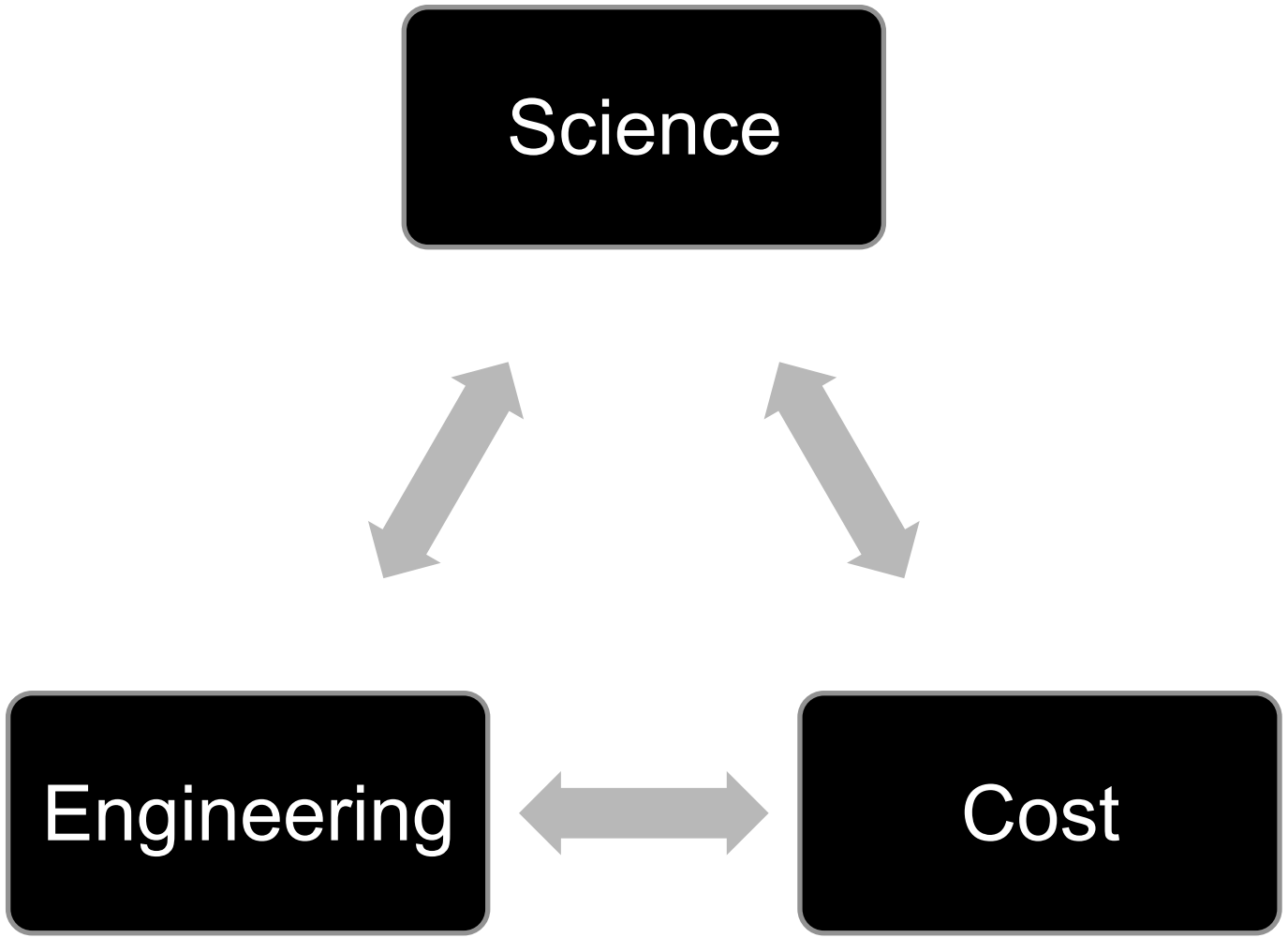
# The Historical Approach: Disadvantages of the Waterfall



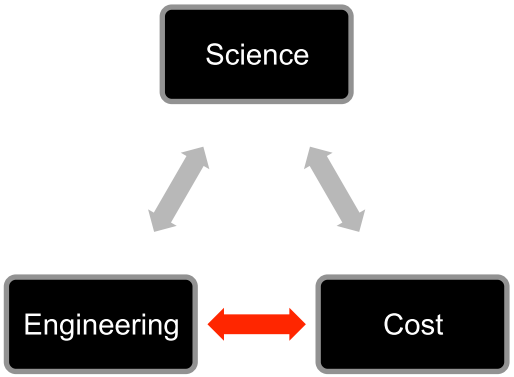

**Waterfall formulation is time consuming, often leads to leads to solutions outside the resource constraints, and can result in proposal weaknesses in Science (pruning), Technical (reaching), Management (cobbling) and/or Cost (pricing)**

# Alternative to the Waterfall: Concurrent & *Collaborative* Engineering

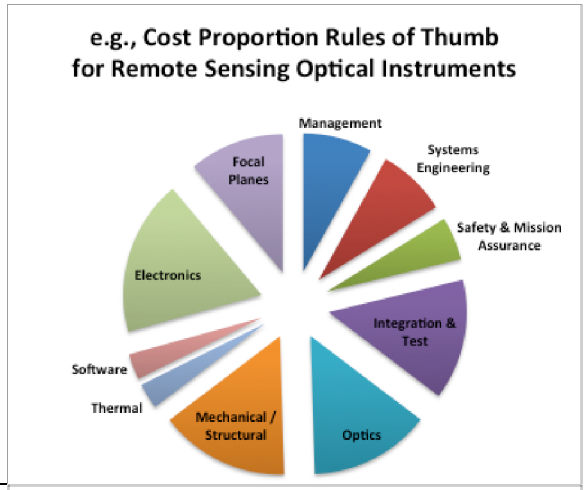


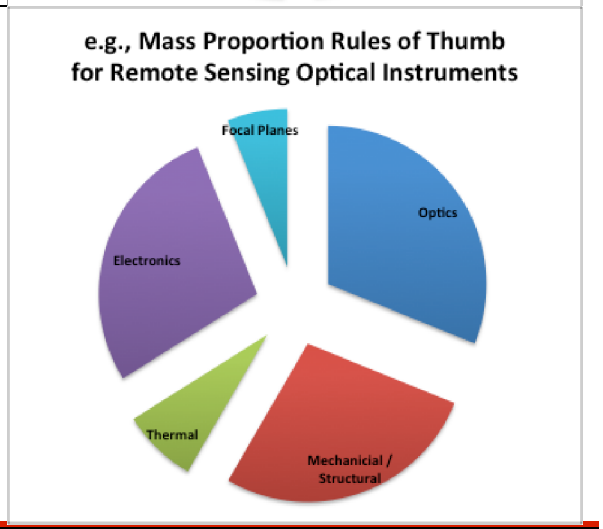

**Enables quick convergence, within the boundaries, and minimizes potential weaknesses**

# Engineering ↔ Cost
# Parametric Models & Rules of Thumb



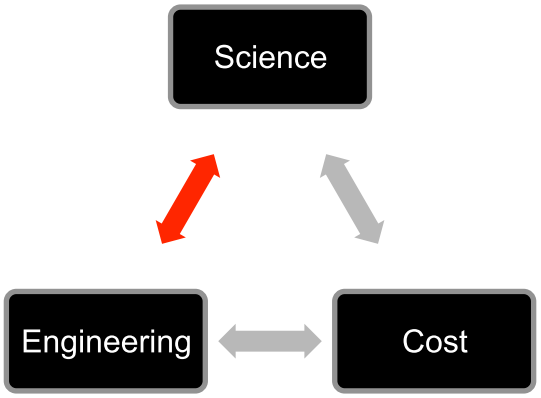

$ = $f$(kg, W, kbps, …)



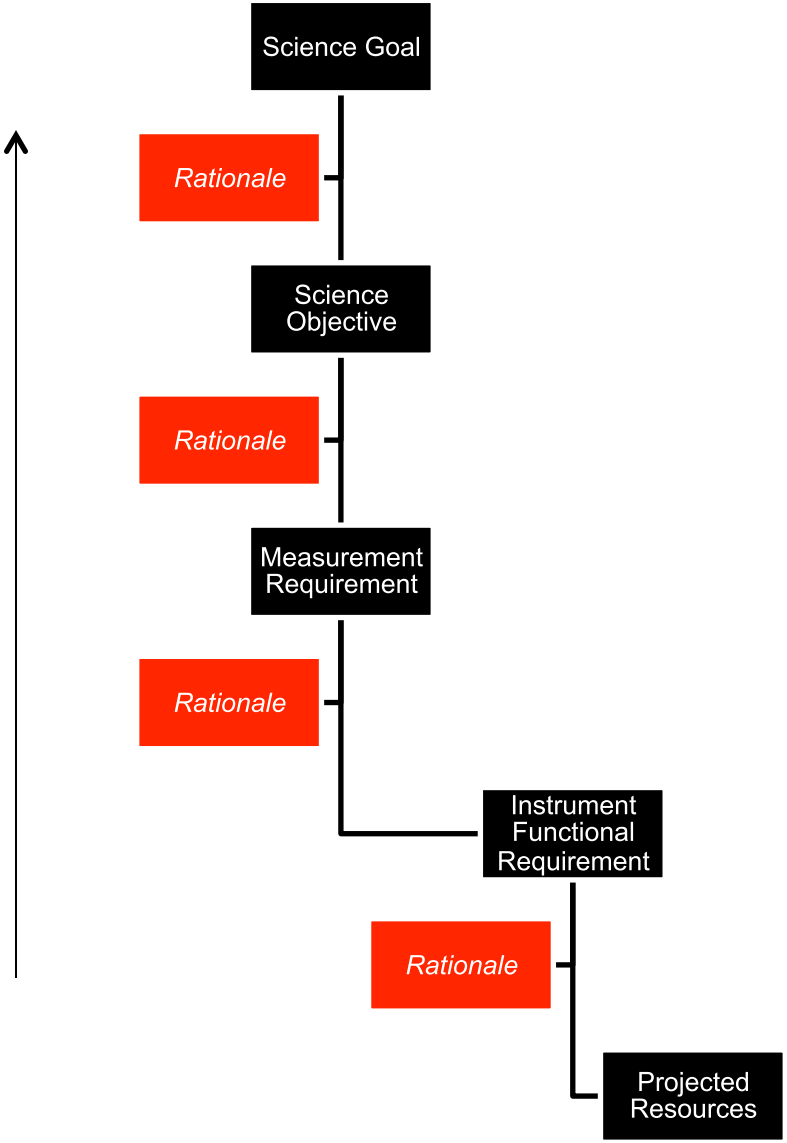




- Left to Right
  - Traditional waterfall direction
- Right to Left
  - Starts *individuals* in "likely" parameter spaces
  - Speeds convergence of team
  - Creates the dynamic tension needed to drive innovation

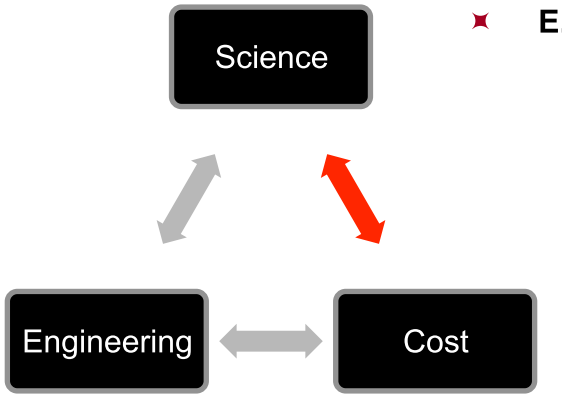
# Science ↔ Engineering
# Testing the Assumptions (Rationale)




- The traceability of each requirement is linked by some *rationale*.
- Whether the through the result of a prejudice, or thorough trade study, untested, the rationale can push the architecture outside the selectable zone
- Systems engineering best practices recommend solving the problems at the lowest possible level



# Science ↔ Cost
# Comparison with *Selected* Missions



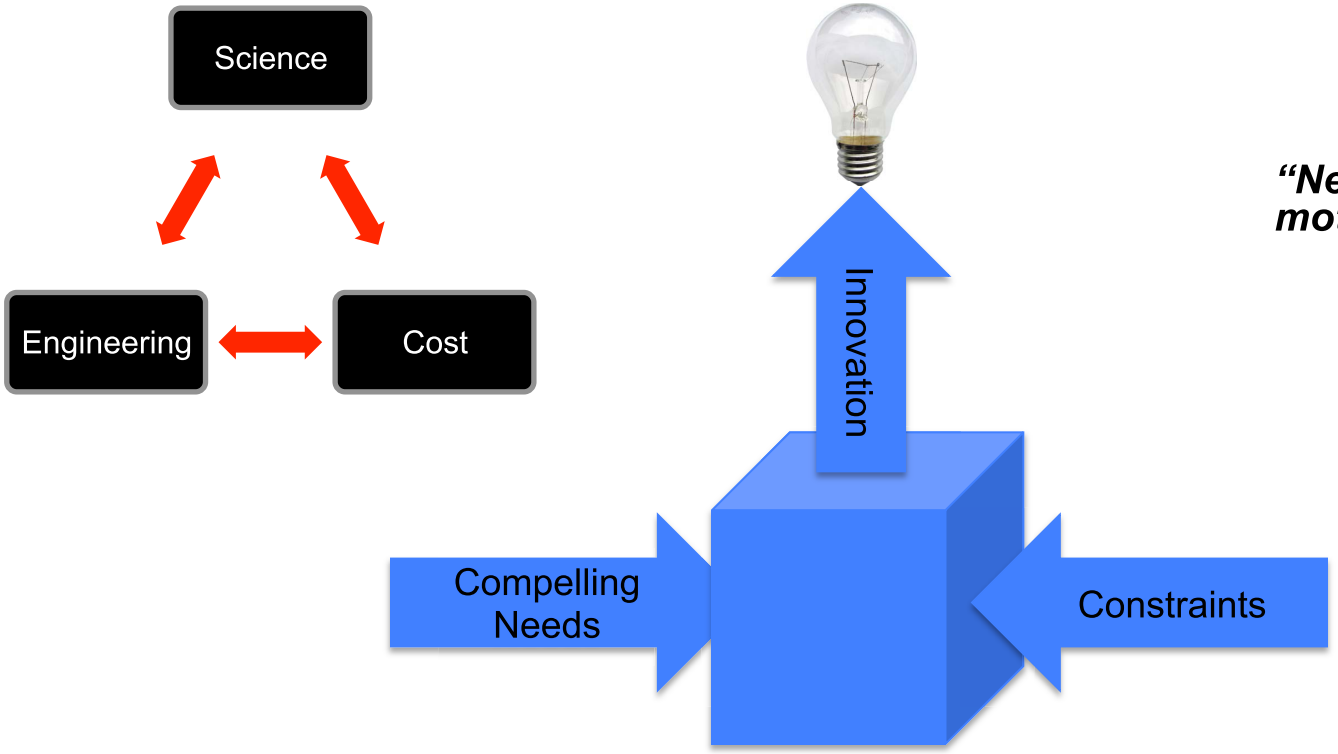

- **E.g., Characteristics of Discovery Missions**
  - Single Planetary Body Orbiters (5 Missions)
    - 6 ± 2 Instruments
  - Multi Body Rendezvous (2 Missions)
    - 6 ± 2 Instruments
  - Sample Return (2 Missions)
    - 3±2 instruments
  - Lander (3 Missions)
    - 6±3 Instruments

Provides a reference for the state of the art *in class*.

Can be used to reveal *trends* (e.g., destination in class)

Reveals potentially selectable solutions consistent with proposal reviewers' expectations (less likely to generate findings of Major Weaknesses)

# Better than the Waterfall: Constraint Driven Innovation




*"Necessity is the mother of invention"*

- **Quickly gets all disciplines looking for solutions in most likely parameter spaces**
- **Leads to solutions within the resource constraints**
- **Results in selectable solutions consistent with proposal reviewers' expectations (less likely to generate findings of Major Weaknesses)**

# Think Inside the Box
# Because It's Bigger On The Inside