The background of the slide is a photograph of the Massachusetts Institute of Technology (MIT) dome building. The dome is a large, white, hemispherical structure with a flat top, situated on a hill. In the foreground, a large crowd of people is gathered on a green lawn, many looking towards the camera. The sky is clear and blue, and there are green trees on either side of the building.

# Heuristics for Systems Engineering Cost Estimation

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Theory is when you know everything, but nothing works.

Practice is when everything works, but no one knows why.

MIT is where theory and practice come together...

Nothing works and no one knows why.

- on the door of a  
laboratory at MIT

# Outline

- Behavioral economics
- Systems Architecting heuristics by Rechten
- Criteria for developing heuristics
- Four categories of heuristics (Qty. of heuristics)
  - Development (5)
  - Calibration (6)
  - Usage (16)
  - Estimation (4)
- Discussion

This presentation is largely based on the paper:  
Valerdi, R., (in press) Heuristics for Systems Engineering Cost Estimation, *IEEE Systems Journal*.

# Acknowledgements

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Ms. Madrazo

# Bottom Line Up Front

1. Heuristics are effective tools for making decisions when little information is available
2. Heuristics are good ways to capture knowledge and teach
3. Longevity does not translate into quality

# Definitions

- Heuristic
  - Rule of thumb, educated guess, simplification, intuitive judgment or *common sense*
  - strategy using readily accessible though loosely applicable information to control problem-solving in human beings
  - Example: ***Work expands so as to fill the time available for its completion\****
- Bias
  - an unfair preference for or dislike of something
  - arises from various life, loyalty and local risk and attention concerns that are difficult to separate or codify
  - Example: **optimism**

\*Parkinson's Principle

# **Rational Choice Theory**

## ***(homo economicus)***

- Modeling of social & economic behavior
- Microeconomic paradigm
- Models of rational choice assume individuals choose the best action according to stable preference functions and constraints facing them

# Prospect Theory

- Describes decisions between alternatives that involve risk, i.e. alternatives with uncertain outcomes, where the probabilities are known
- The model is descriptive
  - attempt to model real-life choices rather than optimal decisions



# Tversky & Kahneman Heuristics

2002 Nobel Prize in Economics

- Representativeness

the degree to which *A* is representative of *B*

*A* = completed project

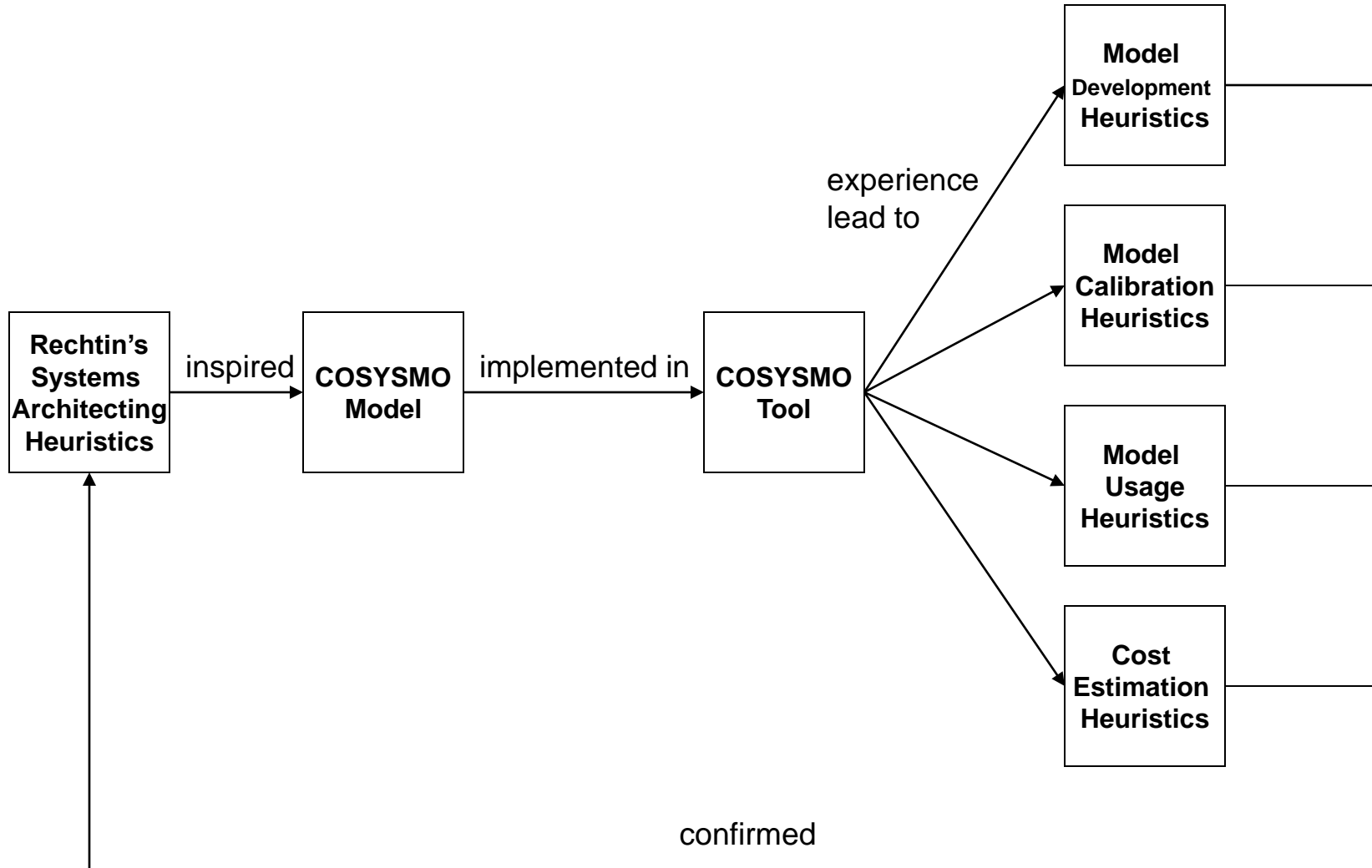
*B* = project being estimated

- Anchoring

- the ability for people to make an estimate by starting from an **initial value** that is adjusted to yield the final answer

- **initial value** = a client's desired project schedule

# Experiential Closed Loop



# Elements of Successful Systems Architects

1. Know the engineering fundamentals on which each architecture is based
  - Common sense, derived from specific engineering fundamentals and the experience of other architects, is needed to reduce the search to practical dimensions
2. Experience and judgment are necessary
  - Hands-on system problem solving is mandatory
3. Acquire the insights gained from experience in the design laboratories on the job

<i>Systems Architecting Heuristic (Rechtin 1991)</i>	<i>COSYSMO Cost Driver</i>
Success is defined by the beholder (understand his or her requirements) not by the architect	Number of System Requirements
The greatest leverage in systems architecting is at the interfaces	Number of Major Interfaces
One person's architecture is another person's system is another person's component	Architecture Understanding
There will always be friction on the "illity" boundary	Level of Service Requirements
If you don't understand the existing system you can't be sure you are re-architecting a better one	Migration complexity
"Proven" and "State of the Art" are mutually exclusive qualities	Technology Maturity
Amid a wash of paper, a small number of documents become critical pivots around which every project manager revolves	Documentation to Match Life Cycle Needs
Organize personnel tasks to minimize the time individuals spend interfacing	# and Diversity of Installations & Platforms
A strong coherent constituency is essential	Stakeholder Team Cohesion

# Criteria for Developing Heuristics

1. Agreement among experts that the heuristic is useful and correct
2. Heuristic must stand the test of time
3. Heuristic must be resilient across different scenarios
4. Heuristic must demonstrate value by
  - reoccurring more than once
  - Not be considered obvious by everybody, particularly people who are new to the field

# Model Development Heuristics

- **Heuristic #1:** More parameters increase the explanatory power of the model, but too many parameters make the model too complex to use and difficult to calibrate.
- **Heuristic #2:** Break the problem and analysis into life cycle phases; the right amount of granularity is important.
- **Heuristic #3:** Let available data drive the application boundaries of the model.
- **Heuristic #4:** Design the rating scale according to the phenomenon being modeled.

# Development-related Heuristic

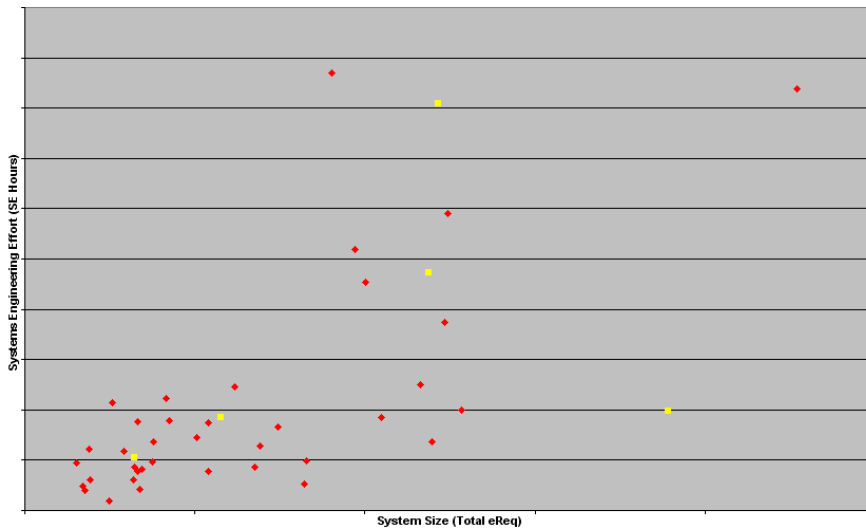
**Heuristic #5:** *Some system characteristics are more likely to be cost penalties than cost savings.*

*Migration Complexity cost driver in COSYSMO*

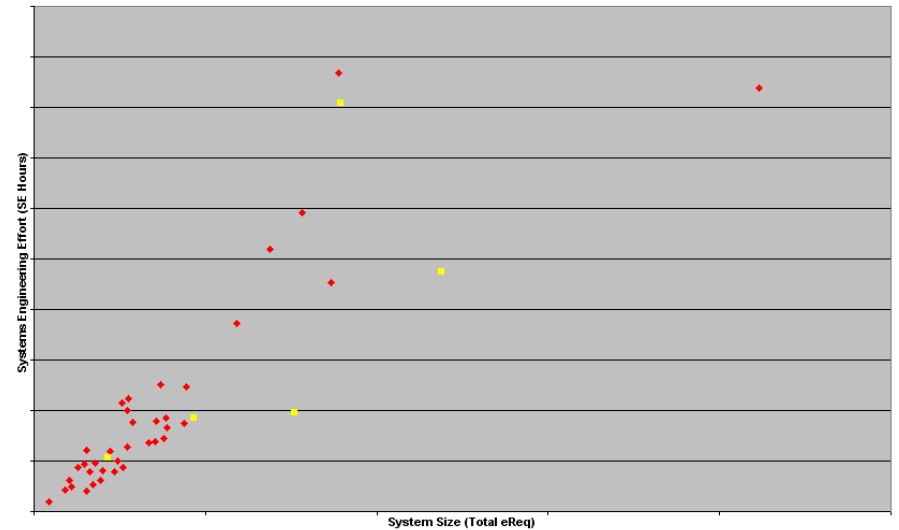
	Nominal	High	Very High	Extra High
<b>Legacy contractor</b>	Self; legacy system is well documented. Original team largely available	Self; original development team not available; most documentation available	Different contractor; limited documentation	Original contractor out of business; no documentation available
<b>Effect of legacy system on new system</b>	Everything is new; legacy system is completely replaced or non-existent	Migration is restricted to integration only	Migration is related to integration and development	Migration is related to integration, development, architecture and design

# Calibration-related Heuristic

***Heuristic #6: All calibrations are local.***



Before local calibration



After local calibration



# Model Calibration Heuristics

- **Heuristic #7:** Calibrations fix chronic errors in over- or underestimation.
- **Heuristic #8:** Be skeptical of data that you did not collect.
- **Heuristic #9:** For every parameter in the model, 5 data points are required for the calibration.
- **Heuristic #10:** Don't do more analysis than the data are worth.
- **Heuristic #11:** You need less data than you think, you have more data than you think.

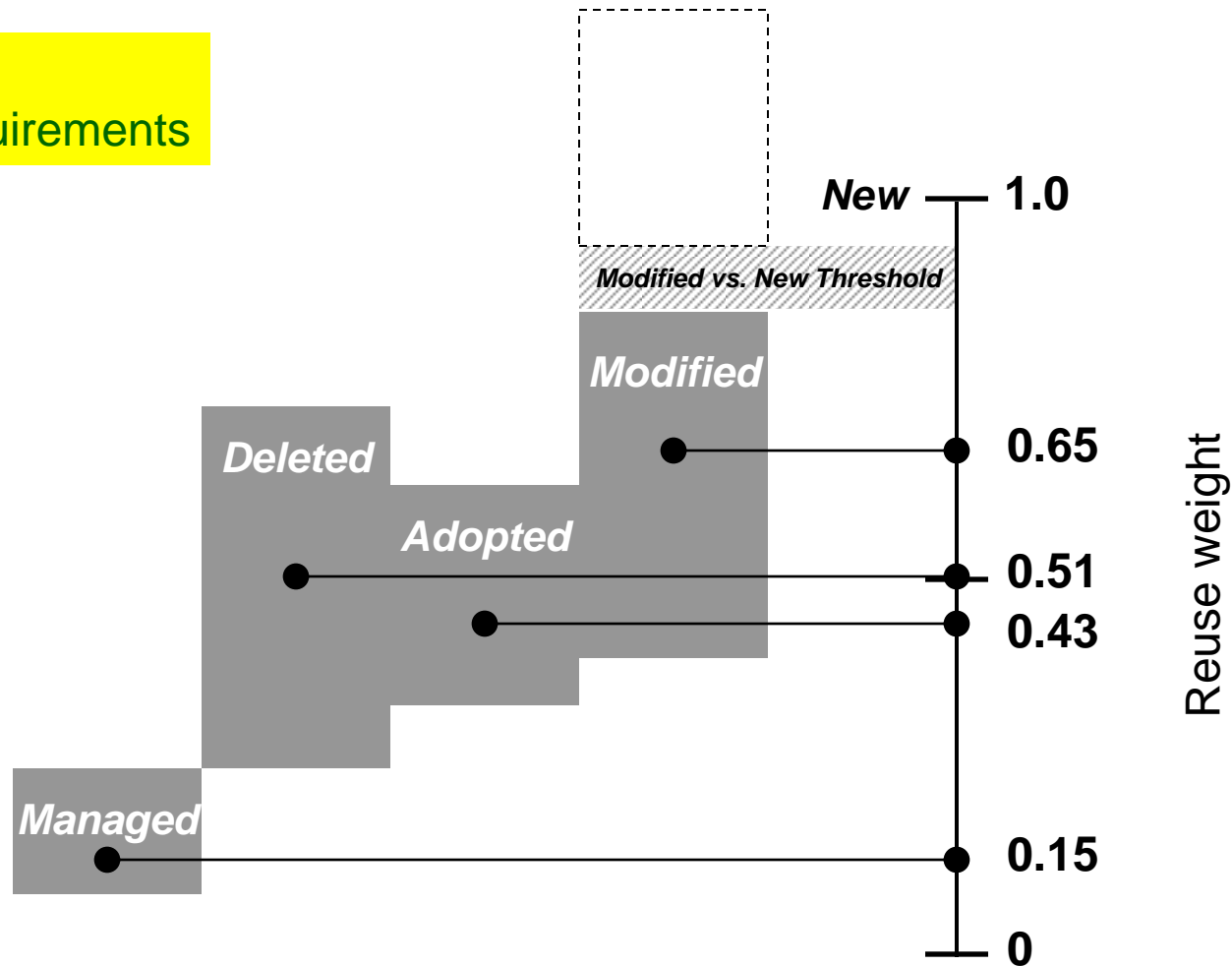
# Usage Heuristics

- **Heuristic #12:** A model is not reality.
- **Heuristic #13:** All models are wrong, but some of them are useful.
- **Heuristic #14:** Begin with the end in mind.
- **Heuristic #15:** Requirements are king.
- **Heuristic #16:** Not all requirements are created equal.

# Usage-related Heuristic

*Heuristic #17: Reuse is not free.*

Example:  
System requirements



# Usage Heuristics II

- **Heuristic #18:** Operational Scenarios may come first, but requirements will ultimately describe the system.
- **Heuristic #19:** Don't double dip.
- **Heuristic #20:** Find your sea level.
- **Heuristic #21:** Nominal is the norm.
- **Heuristic #22:** If you're estimating a large project, personnel capability is Nominal.
- **Heuristic #23:** Most of your off-Nominal cost drivers should match your last project.

# Usage Heuristics III

- **Heuristic #24:** If you're going to sin, sin consistently.
- **Heuristic #25:** Use a combination of models to estimate total system cost.
- **Heuristic #26:** Avoid overlap between models.
- **Heuristic #27:** Estimate using multiple methods (analogy, parametric, etc.)

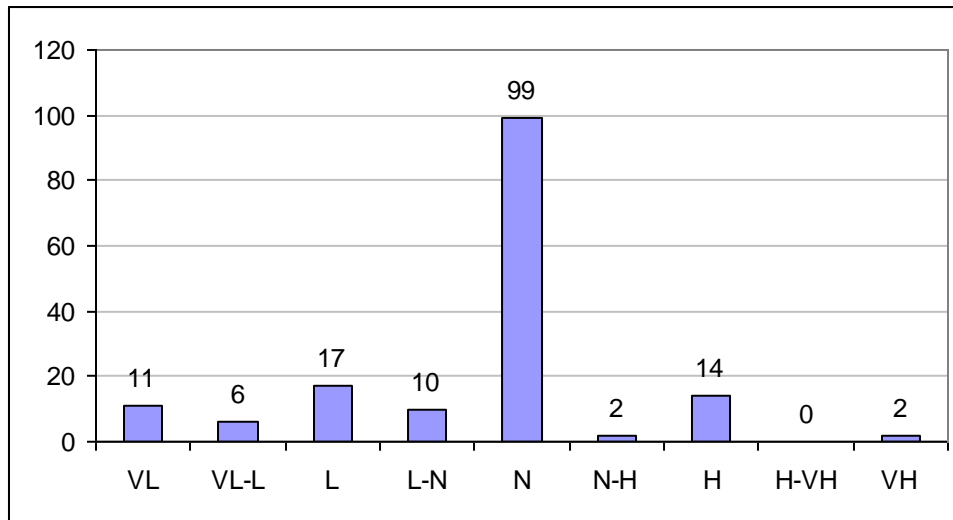
# Estimation Heuristics

- **Heuristic #28:** Estimate early and often.
- **Heuristic #29:** Experts all disagree forever.  
Bound the options they are given to evaluate.

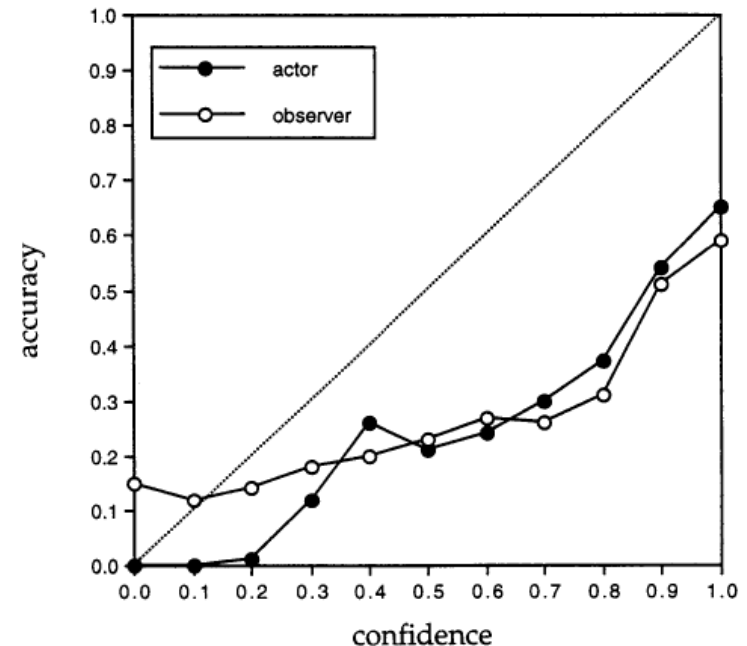
# Estimating-related Heuristic

**Heuristic #30:** Models are optimistic.

**Heuristic #31:** People are generally optimistic.



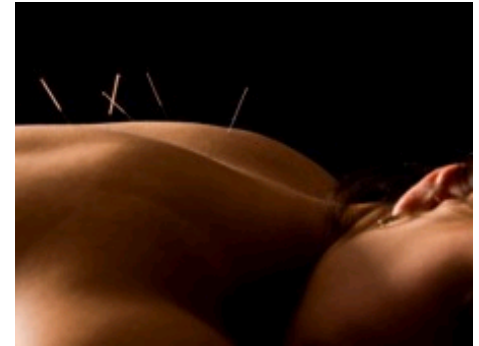
SCED on COCOMO II Database



Koehler, D. J., Harvey, N. (1997). Confidence judgments by actors and observers. *Journal of Behavioral Decision Making*. 10, 221-242.

# Longevity Bias

1. Lure of tradition proves persistent
  - *If something has been around longer, it must be better (wrong!)*
2. We hold onto 'longevity' even in instances where quality has nothing to do with longevity
3. Unfortunately, it may confer legitimacy on otherwise undesirable practices





# ...Bottom Line (Again)

1. Heuristics are effective tools for making decisions when little information is available
2. Heuristics are good ways to capture knowledge and teach
3. Longevity does not translate into quality