Educating Engineers or Training Technicians

Understanding at the Conceptual Level

Agenda

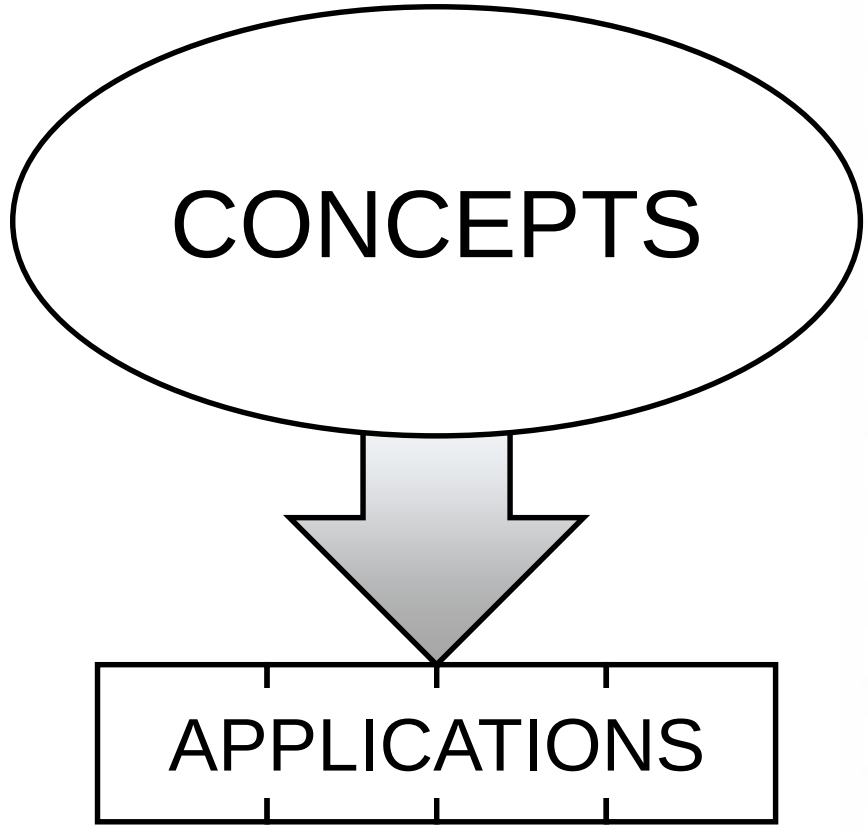
- Conceptual framework
- Bias toward practicality
- History of development
- Resulting barriers
- Path forward

Conceptual Framework

Engineers v. Technicians

- US Dept. of Labor, Bureau of Labor Statistics
- Electrical engineer- “Research, design, develop, test, or supervise the manufacturing and installation of electrical equipment, components, or systems for commercial, industrial, military, or scientific use.”
- Electrician- “Install, maintain, and repair electrical wiring, equipment, and fixtures. Ensure that work is in accordance with relevant codes.”

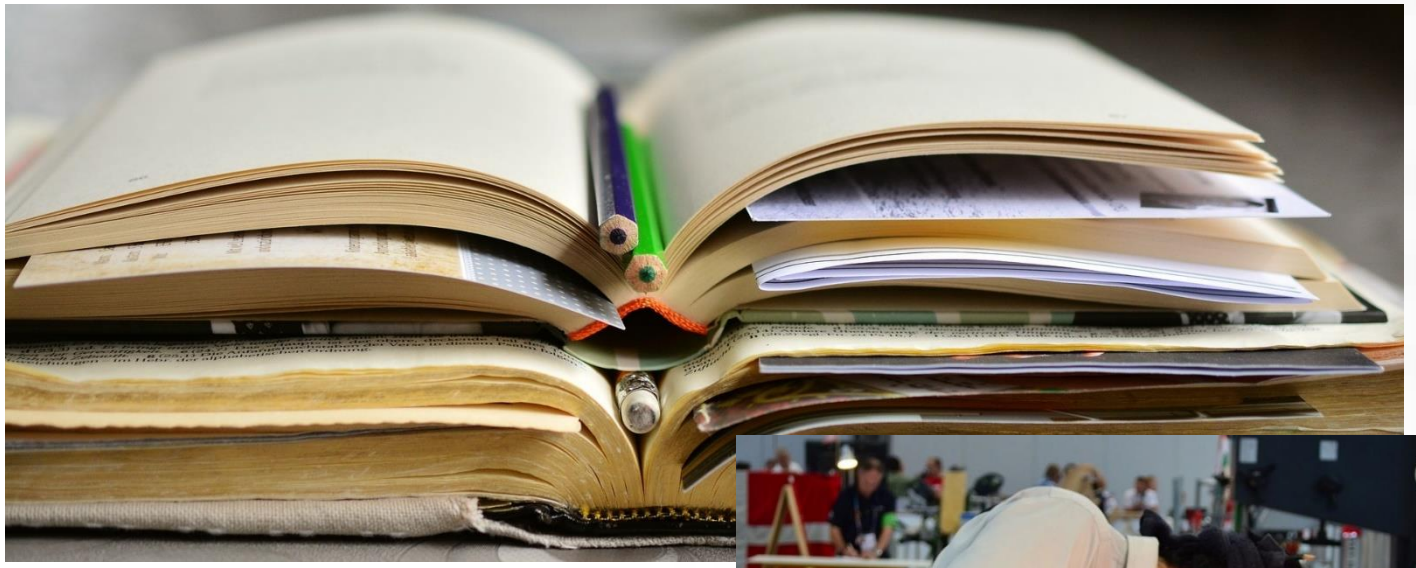
Electrical Engineering = Concepts


CONCEPTS
APPLICATIONS

Education v. Training

Definitions

- Education- the act of imparting or acquiring general knowledge, developing the powers of reasoning and judgment
- Training- the action of teaching a person a particular skill or type of behavior
- Concepts v. skills



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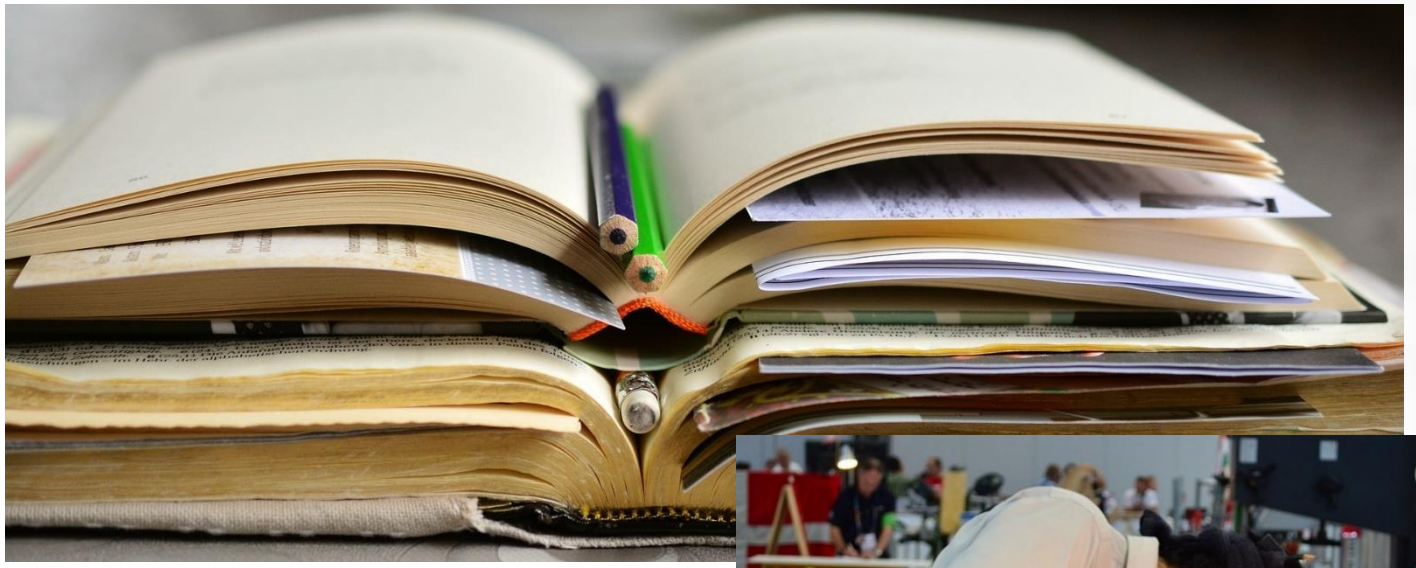
Bias

- “training gives you the skills to do something rather than just know about something”

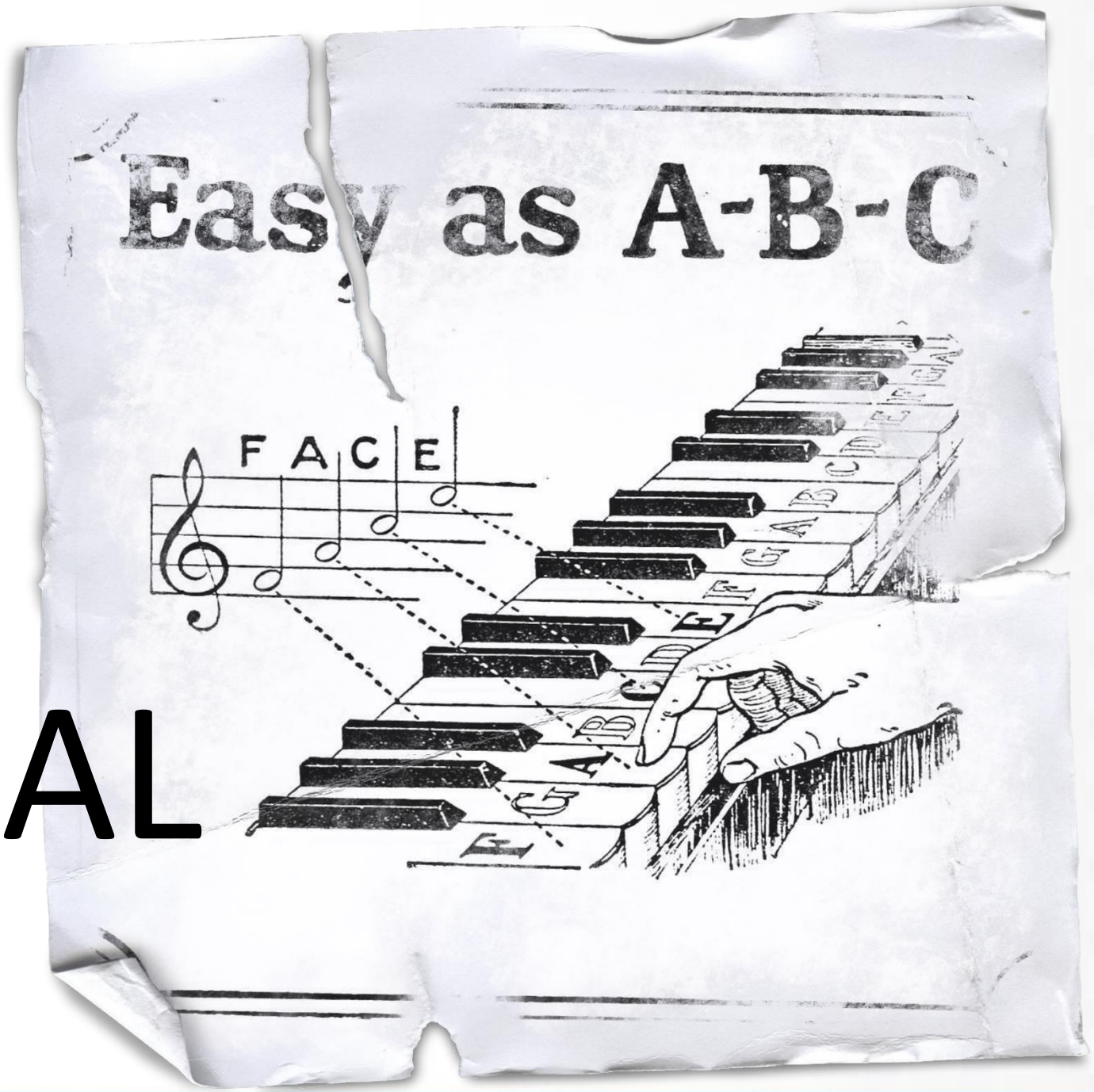


Do

rather than

just know

PRACTICAL



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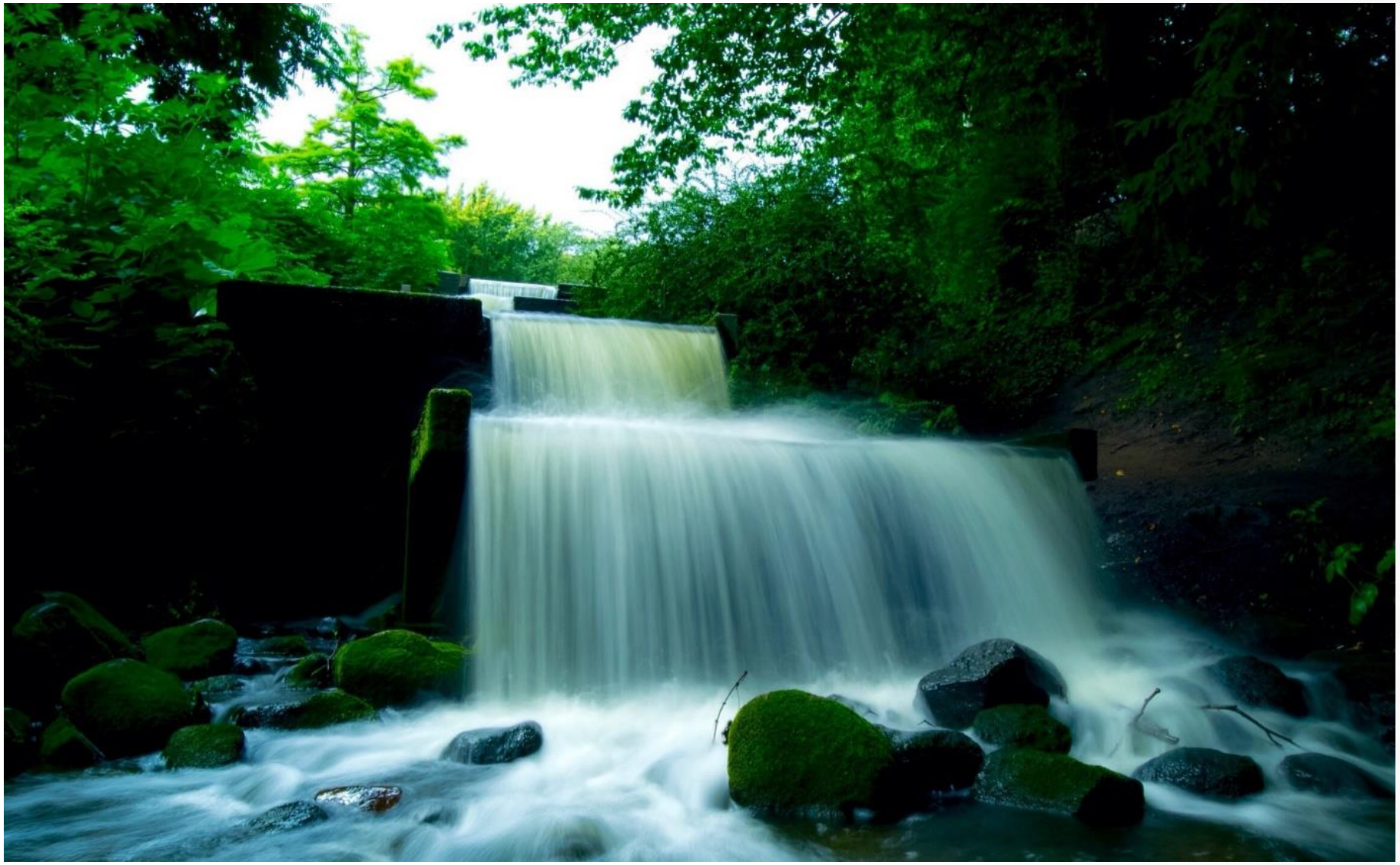
Defining Systems Engineering-Process

History

- Waterfall



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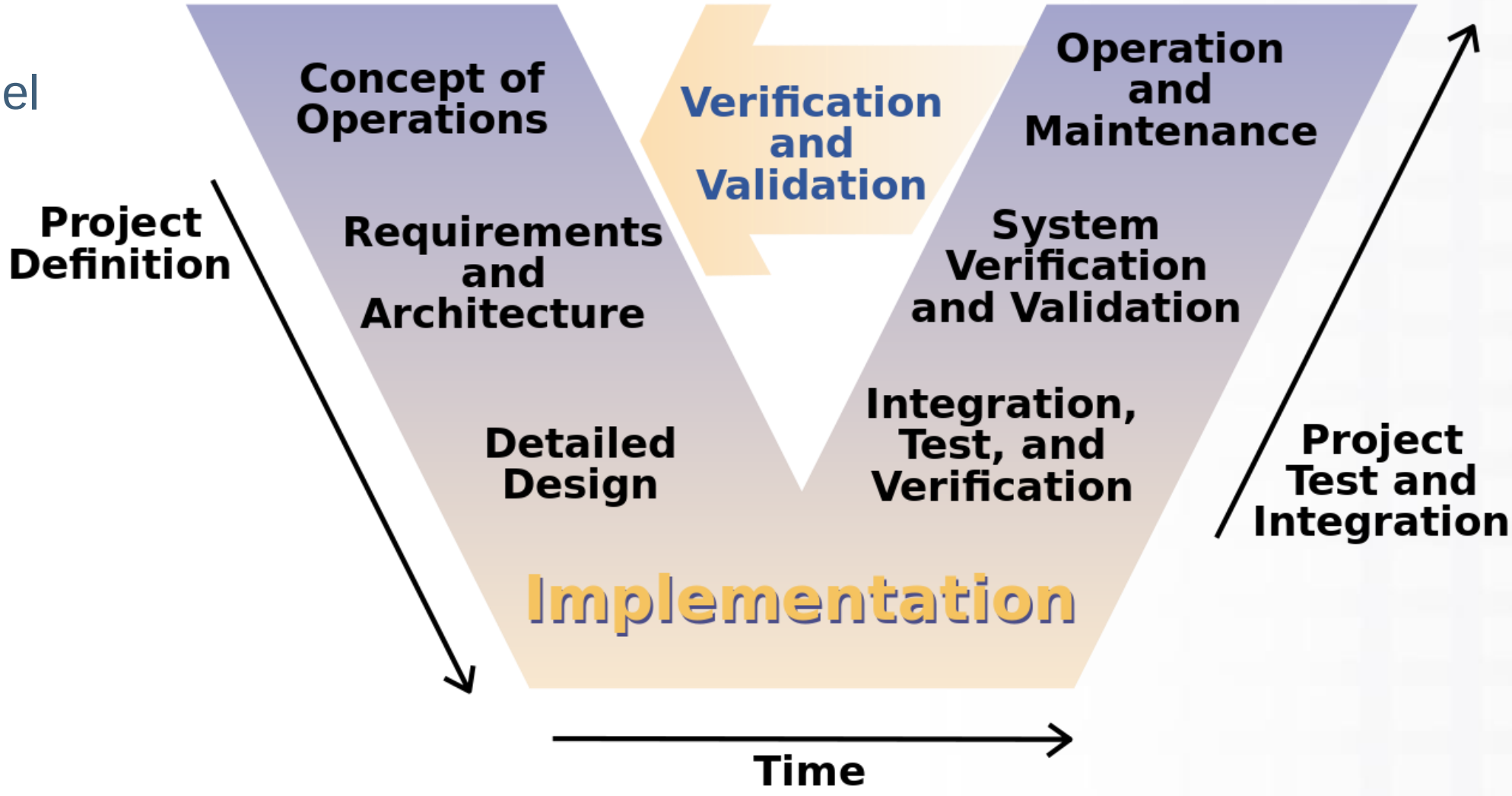
History

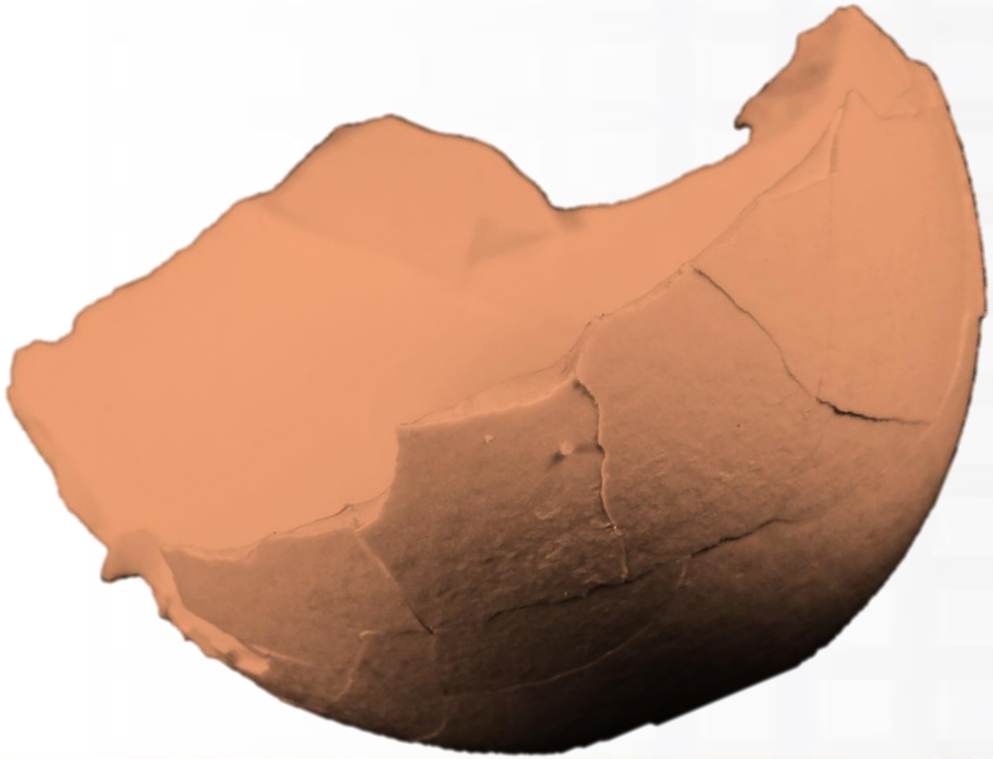
- Waterfall
- Vee- model

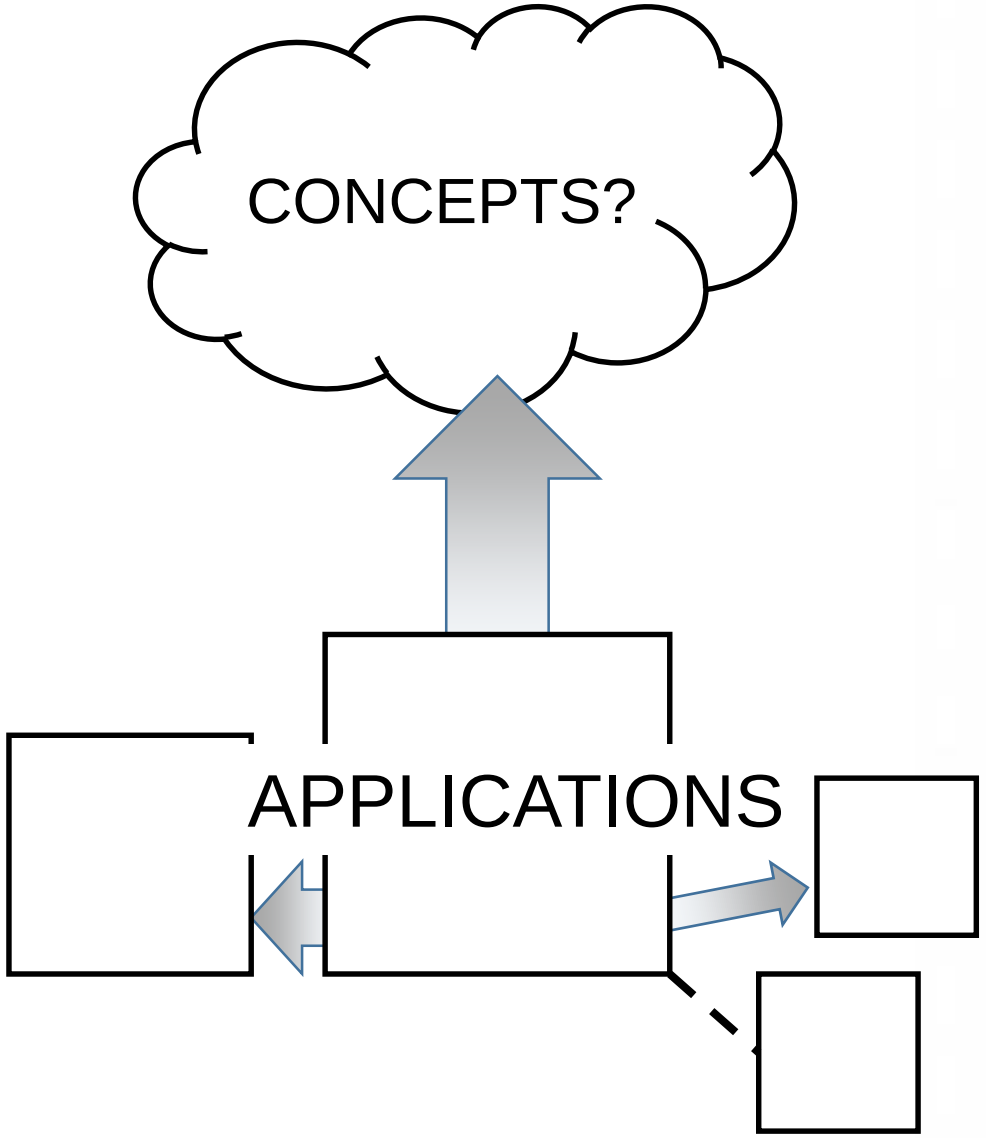


Early definitions

- MIL STD 499
- EIA 632 response to DoD cancellation of MIL STD 499
- Electronic Industries Alliance (EIA) composed of representatives from:
  - DoD,
  - Aircraft Industry Association (AIA),
  - National Security Industries Association (NDIA),
  - Institute of Electrical and Electronics Engineers (IEEE), and
  - INCOSE
- IEEE 1220 (1998), Standard for Application and Management of the Systems Engineering Process
- Process definition

Systems Engineering = Process

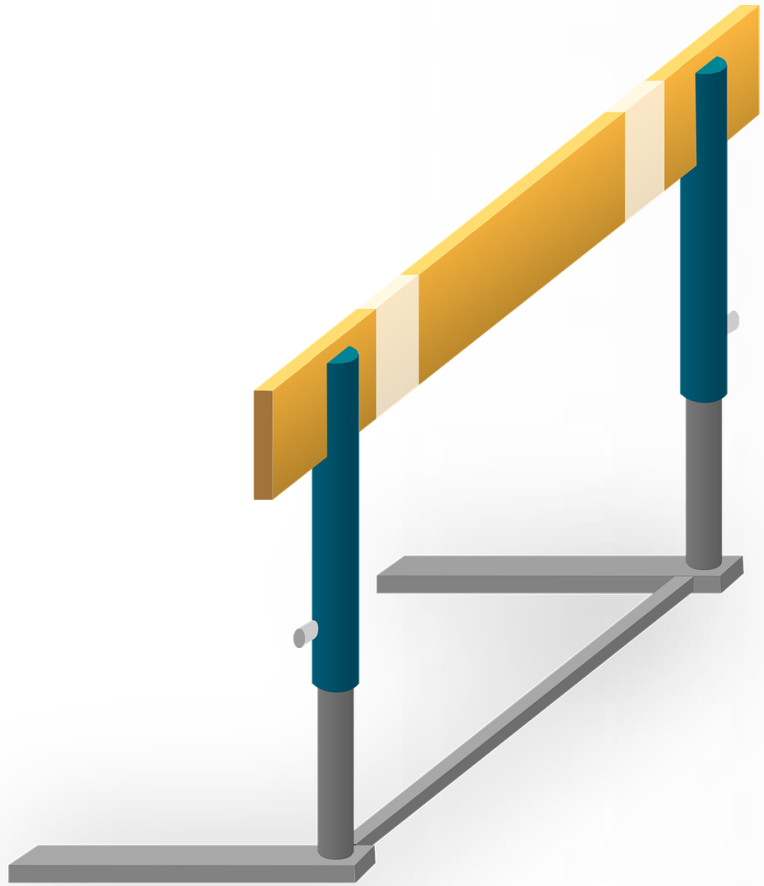



CONCEPTS?
APPLICATIONS

How is that a problem?

- Others don’t recognize processes
- Already tailored
  - Military
  - Aerospace
  - Electronics
  - Software

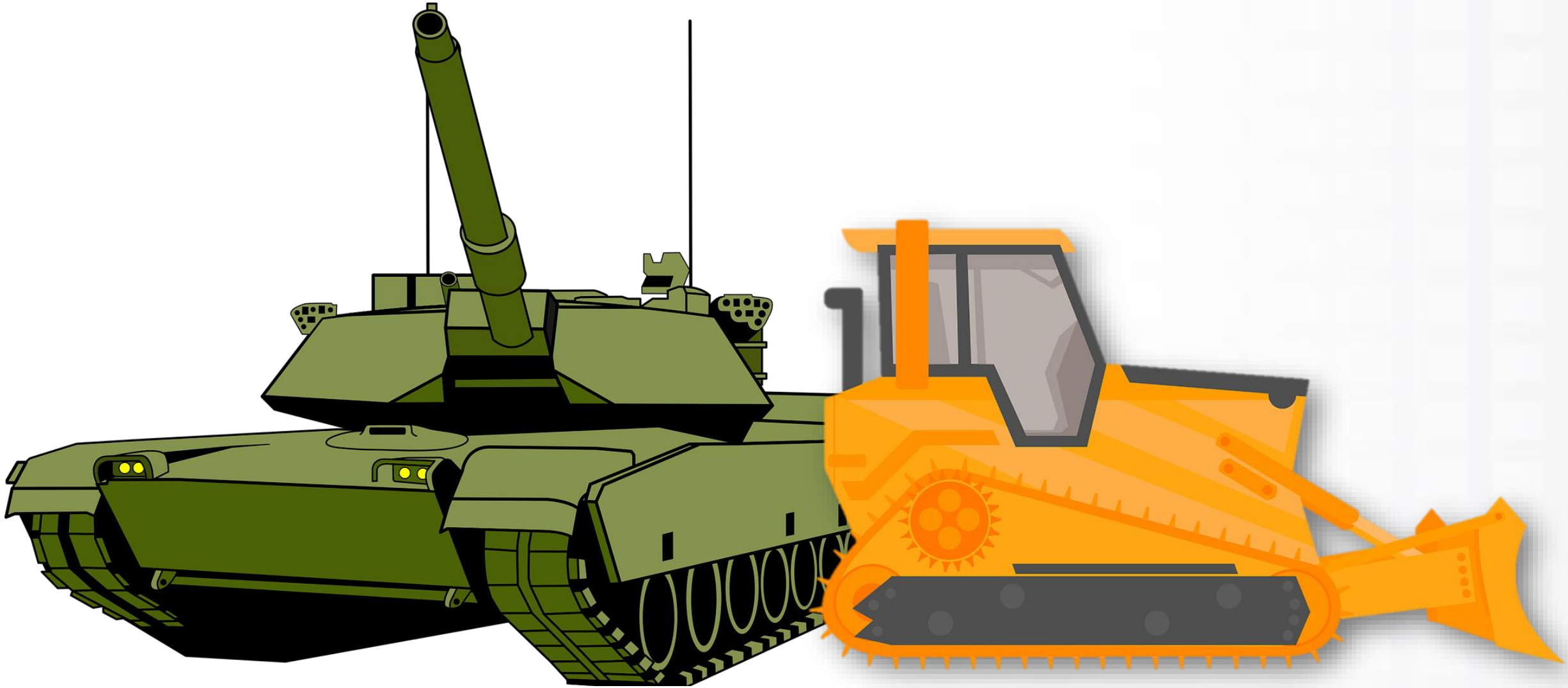
Hurdles



Language

- Jargon
  - SRS, SSDD, SSS
- Confusion
  - Ex.- Failure mode effects analysis (FMEA)
    - Meaning- ASQ, FDA, Oil and Gas, DoD (FMECA)
    - Mil Std 1629A cancelled- move to “commercial standard”
  - “Agnostic”

Contextual vision- This works



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Contextual vision- This? Not so much!

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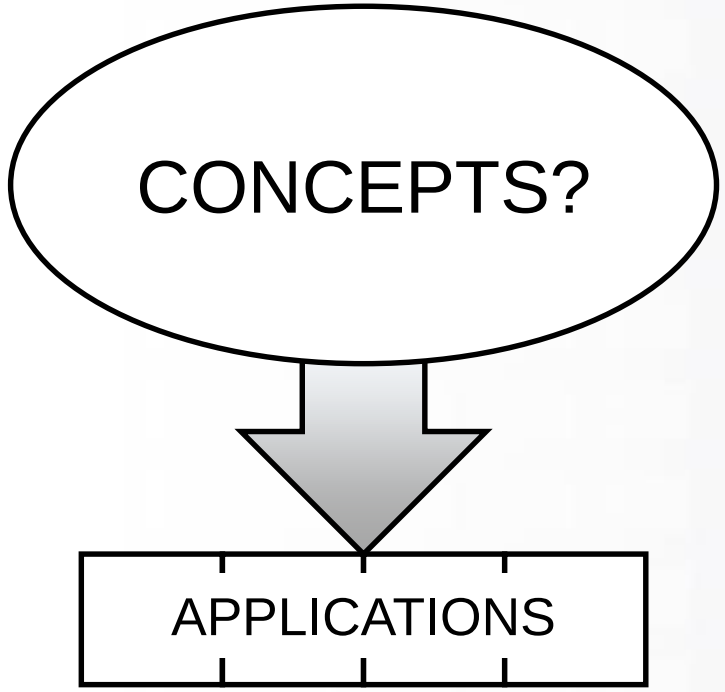

Systems Engineering

Example- Systems Thinking

- “The standard systems engineering process breaks down a problem into parts, recursively, until the parts are simple enough that we understand them and can design solutions; we then re-assemble the parts to form the whole solution.” A Complexity Primer for Systems Engineers, INCOSE, Sheard, et al (2016)
- “In systems thinking, increases in understanding are believed to be obtainable by expanding the systems to be understood, not by reducing them to their elements. Understanding proceeds from the whole to its parts, not from the parts to the whole as knowledge does.” Russell Ackoff

Example- Complexity

- “But busy systems engineers rarely have the time to keep up with this literature, which is diffused across the many interdisciplinary applications of complex systems science.” A Complexity Primer for Systems Engineers, INCOSE, Sheard, et al (2016)
- Detail v. dynamic; physical v. adaptive
- All systems produce results not possible for any of their elements- this is particularly problematic for complex systems
- Managing complexity
- Desirable complexity- adaptability and resilience

Path Forward

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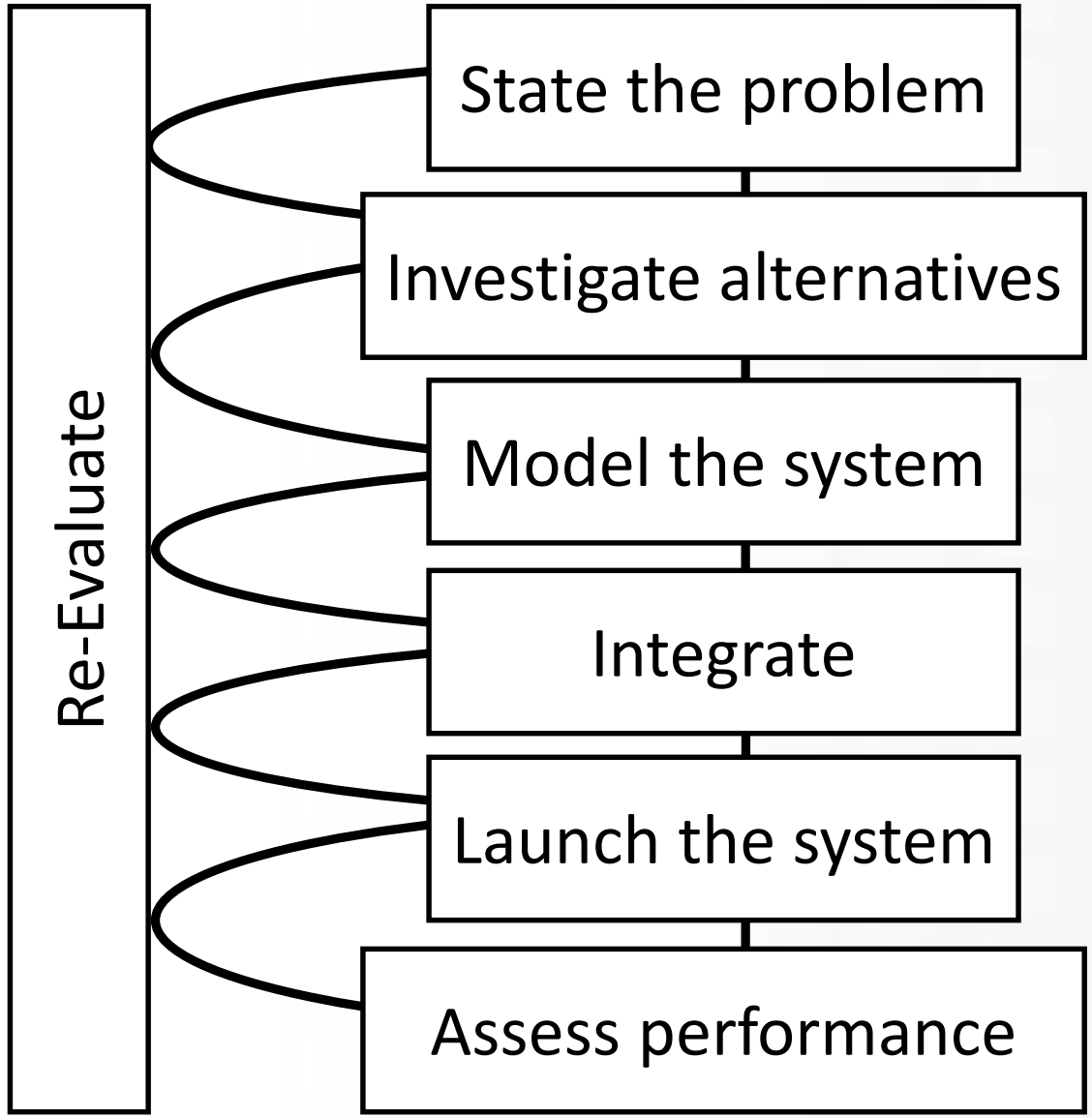
Toward a more natural language

"Unless people can express themselves well in ordinary (language), they don't know what they are talking about." Russell Ackoff

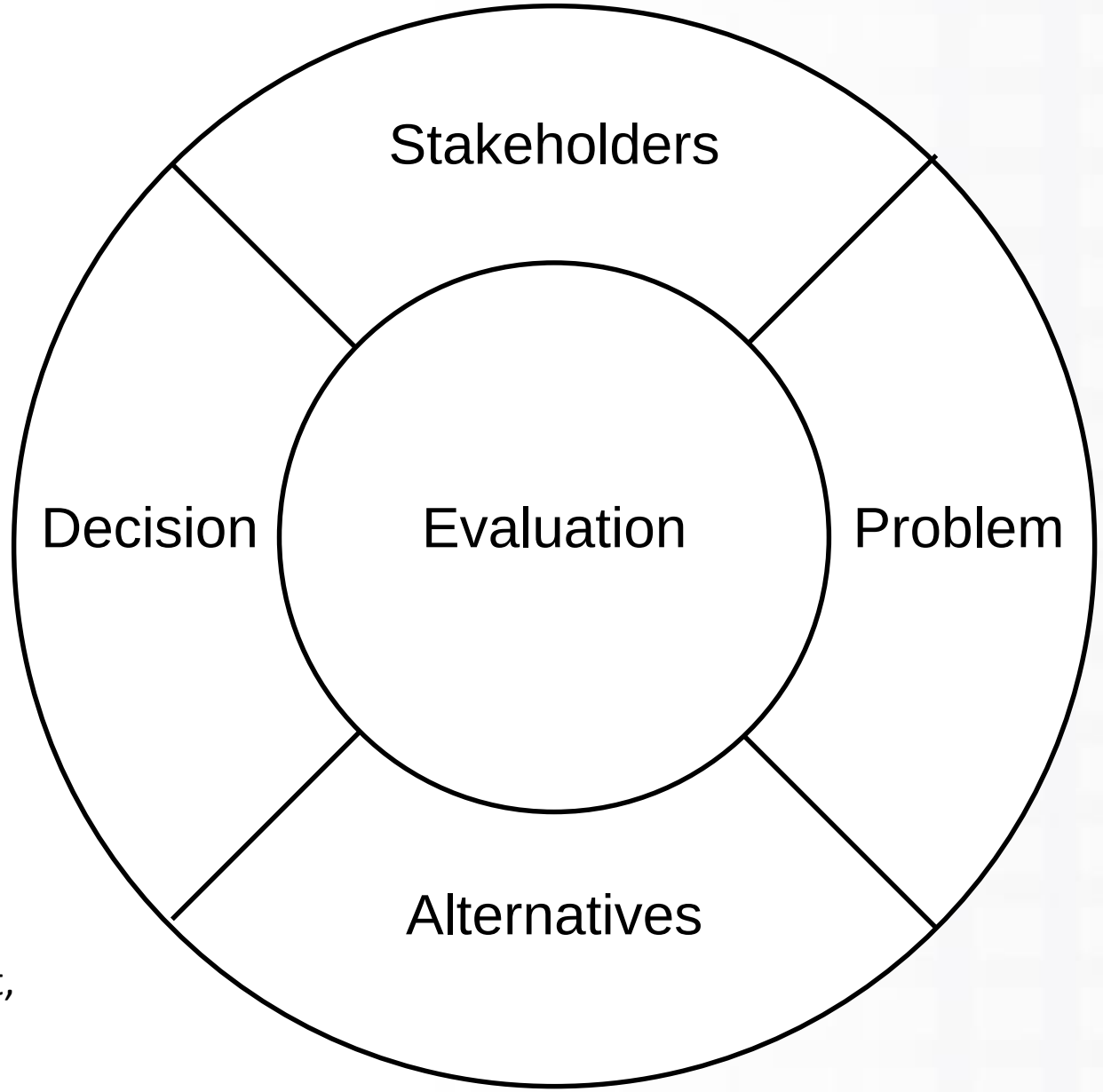
Example-SIMILAR Process

- Bahill & Gissing (1998)



Example- SPADE

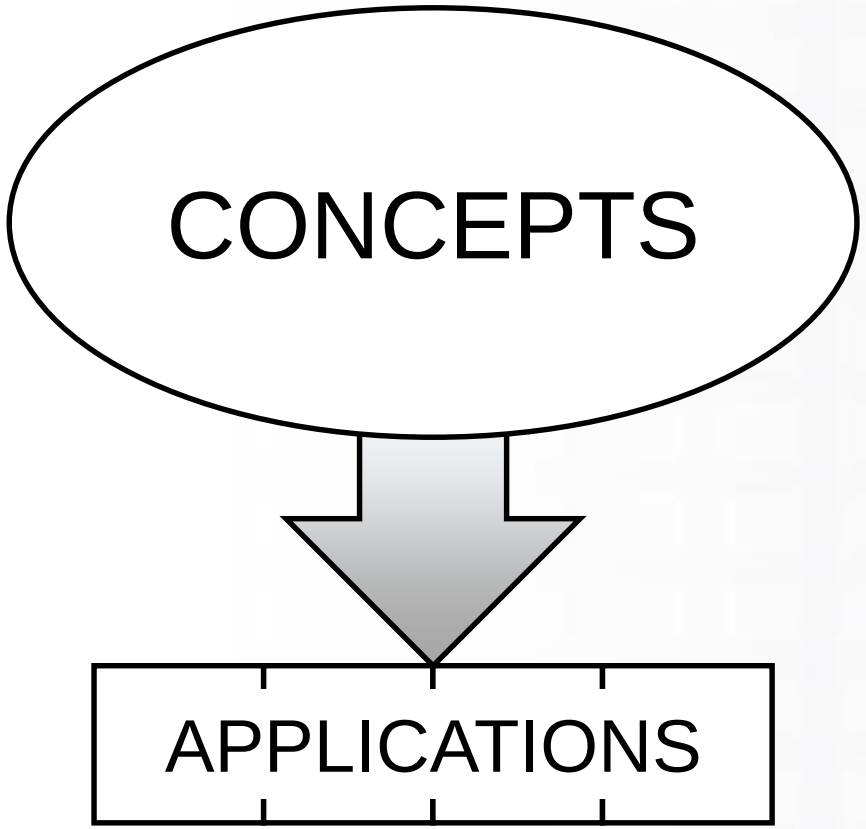
- Haskins (2008)*
  - Stakeholders
  - Problem
  - Alternatives
  - Decision-making
  - Evaluation



* Systems engineering analyzed, synthesized, and applied to sustainable industrial park development, Cecilia Haskins, PhD Thesis, NUST (2008)

Concepts first . . . then application

- Education
  - Systems thinking
  - Complexity
- Training
  - Processes
  - Tailoring



Summary

- Systems engineering developed largely in a specific market segment
- It was defined in terms of processes (as opposed to concepts)
- The processes were highly tailored
- Language was tailored as well
- Transferability (to other domains) is difficult
- We need to learn to see systems engineering at the concept level
- We need to learn to speak in a language (languages?) that others understand
- We need to tailor the solution to the need (not tailor the need to the solution)

Thank You!

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