Systems Engineering Philosophical Questions

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Topics

- **What do we mean by "Philosophical" Questions?**
- Some Important Systems Engineering "Philosophical" Questions
  - Introduction
  - Discussions
- Wrap-up/Summary

“Philosophical” Questions

- Questions that really have no “right” answer
- However, both “sides” usually have very strong opinions
- And the other side is obviously “wrong”

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Examples of Philosophical Questions

USA

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And Perhaps the Most Important Philosophical Question

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Topics

- What do We Mean by “Philosophical” Questions?
- **Some Important Systems Engineering “Philosophical” Questions**
  - **Introduction**
  - **Discussions**
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Some Important Systems Engineering "Philosophical" Questions

- Is Systems Engineering "earned" or "learned"?
- Is Systems Architecting part of Systems Engineering or separate from Systems Engineering?
- Are humans part of your System of Interest (SOI) or do they interface with your SOI?
- Is cost a Technical Performance Measure (TPM)?

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SE Earned vs. Learned?

- Arguments for **earned**
  - Nothing can replace the "school of hard knocks"
  - Need deep understanding of a "core" discipline
  - "Book smarts" without practical engineering judgment is not only inferior, but potentially dangerous
  - Many SE graduate degree programs, and the INCOSE CSEP, require at least 5 years of experience
- Arguments for **learned**
  - Fundamentals can be learned
  - Like everywhere, SE tools & techniques are continually evolving and changing – more seasoned Systems Engineers might be unaware of them, or unwilling to keep current
  - Deep discipline knowledge may cause bias
  - The 5 year requirement is arbitrary

SE Earned vs. Learned Discussion

- There are merits for each position
- This somewhat relates to “nature vs. nurture” in child raising, leadership, etc.
  - A “systems thinking disposition” may be more nature
  - However, one could argue that both earned and learned fall more under nurture
- This could also relate to one’s personality type (e.g., MBTI, Strength Finder)
- Mostly it depends on timing – junior and senior SEs may result in different answers

What is a Systems Engineer?

- An engineer in any field can (and should) apply the “Systems Engineering process” to his or her “system”
  - But this does not necessarily qualify them as a “Systems Engineer”
- There is a marked distinction between:
  - One who simply understands and can apply the Systems Engineering process to their discipline and
  - A trained, experienced Systems Engineer

- Four key aspects of a successful lead Systems Engineer
  - Appropriate **soft skills** (General Cognitive Characteristics, Abilities, Behavioral Competencies) and a **disposition to systems thinking**
  - Knowledge of the **discipline** of Systems Engineering and the ability to wisely apply the correct SE methodology/tools at the correct time
  - Knowledge of the **domain** (automotive, biomedical, energy, infrastructure, mil/aero, etc.)
  - Knowledge of the **organization** (decision making, funding, structure, culture, etc.)

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Architect vs. Engineer?

- Arguments for **part of SE**
  - Architecting cannot be done in isolation
  - It is just one (of many) things that Systems Engineers do
  - SE standards and the INCOSE SE Handbook all include it
  - Diminishes SE
- Arguments for **separate discipline**
  - Follows civil/building traditions
  - Architecting is more of an art than a science
  - Separate standards and textbooks exist for systems architecting
  - Different dispositions are needed for architects
  - Elevates System Architecting

Architecture vs. Design

SEHv4 §4.5

- System Architecture
  - Focuses on the understanding and resolution of the stakeholder concerns
  - Deals with high-level principles, concepts, and characteristics
  - Represented by general views or models excluding details
  - Focuses on suitability, viability, and adaptability over the life cycle
  - Is as design-agnostic as possible to allow for maximum flexibility in the design trade space
  - Focuses more on the “what”
- System Design
  - Supplements the system architecture
  - Driven by specified requirements, the architecture, and more detailed analysis of performance and feasibility
  - Provides information and data useful and necessary for implementation of the system elements
  - Details the expected properties allocated to each system element to enable their implementation
  - Focuses more on the “how” or “implement-to”

Adapted from: (INCOSE SEH, 2015)

Architect vs. Engineer Discussion

- Both sides have strong proponents
- May depend on the size of the effort
  - Small projects: the (one) Systems Engineer may be the only person, and, by definition, the architect
  - Large projects: may have a team of architects
- Many companies define separate Systems Architect, Systems Engineer, Systems Integrator, etc. roles
- If separate roles exist, they must be clearly delineated
- While there may be value in separating the role of architect in some instances, what is more important is to recognize the critical relationships that exist between all of the systems engineering processes
- Without effective communication and coordination, any SE effort is likely to be less effective than it could be
- Either way, architecting cannot be done in isolation

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Human w.r.t. SOI?

- Arguments for **part of the SOI**
  - In many systems, the human performs key functions
  - If the system automates those functions, they are certainly part of the SOI (why not so if done by the human?)
  - INCOSE SE Handbook Usability/HSI section states humans are treated as an integral part of the system
- Arguments for **interfaces with the SOI**
  - We do not “implement” the human system elements
  - Humans are a critical, yet dynamic and highly variable, part of our overall systems solution
  - Usually, only the “operator” is included within the boundary of SOI by “the other side,” and there are many additional humans that interact with your SOI

Machines vs. Humans

Machines Excel In	Humans Excel In
Activities Towards Decision-Making - Performing routine, repetitive, or very precise operations - Storing and recalling large amounts of information - Performing complex and rapid computation with high accuracy - Operating in hostile environments or beyond human tolerance - Deductive processes	Activities Towards Situation Awareness - Perceiving patterns and recognizing generalizations about them - Storing information for long periods of time and recalling relevant facts at the appropriate moments - Exercising judgment, especial under ill-defined or new circumstances - Improvising and using flexible procedures - Reacting to unexpected low-probability events - Reasoning inductively
Other Activities - Monitoring (both humans and other machines) - Sensing beyond human sensitivity - Responding very quickly - Performing simultaneous tasks - Insensitivity to extraneous factors	Other Activities - Sensing certain forms of very low energy levels - Sensing an extremely wide variety of stimuli - Performing fine manipulations, especially where misalignment appears unexpectedly - Continuing to perform while overloaded

Adapted from: (Hew, 2009)

Human w.r.t. SOI Discussion

- The answer to this philosophical question depends on perspective and timing
  - When you are performing a functional analysis of your SOI, you better include the functions that you expect the humans to perform as part of your functional architecture
  - However, as you define the functional and physical interfaces between your SOI and the humans, you should focus on usability from an interfacing perspective
- Systems engineers need to seamlessly swap between these two paradigms

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TPMs

SEHv4 §5.7

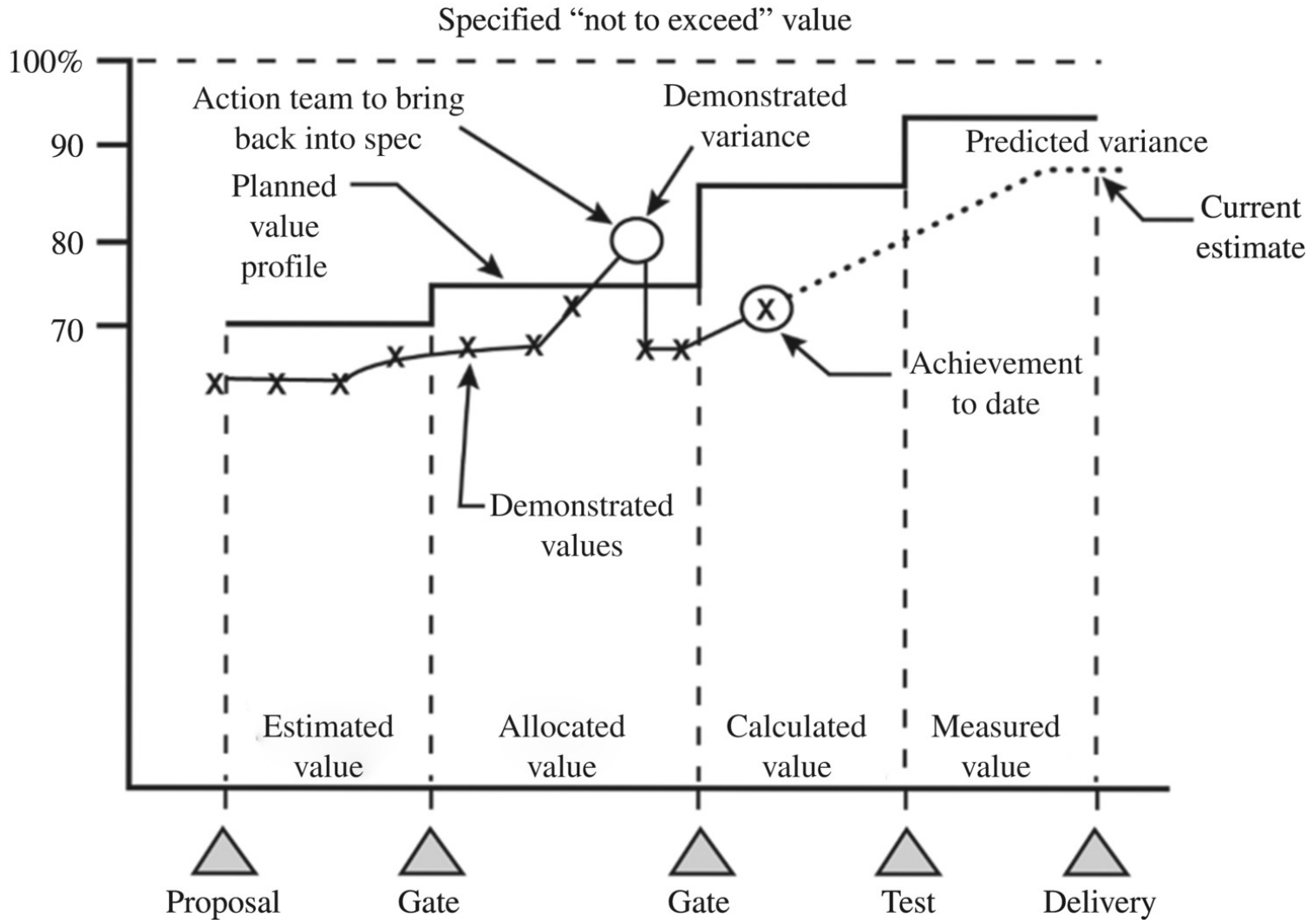
"TPMs measure attributes of a system element to determine how well a system or system element is satisfying or expected to satisfy a technical requirement or goal."

- TPMs
  - Used to assess design progress, compliance to performance requirements, or technical risks
  - Provide visibility into the status of important project technical parameters to enable effective management, thus enhancing the likelihood of achieving the technical objectives of the project
  - Are derived from or provide insight for the MOPs
  - Focus on the critical technical parameters of specific architectural elements of the system as it is designed and implemented

Adapted from: (INCOSE SEH, 2015)

TPM Monitoring

SEHv4 §5.7



Source: (INCOSE SEH, 2015 – Fig 5.14)

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You Want a Few Key TPMs that "Compete" with Each Other

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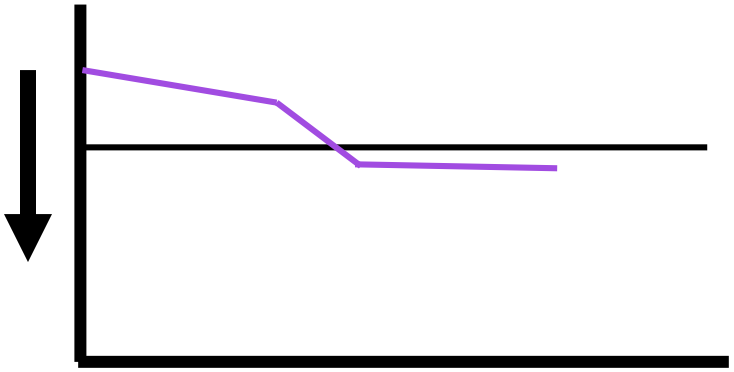
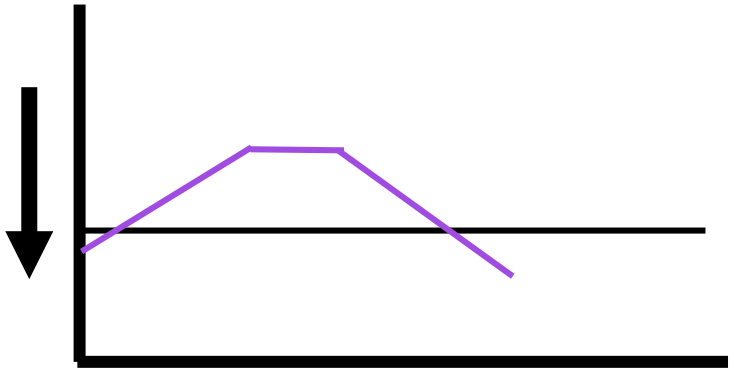
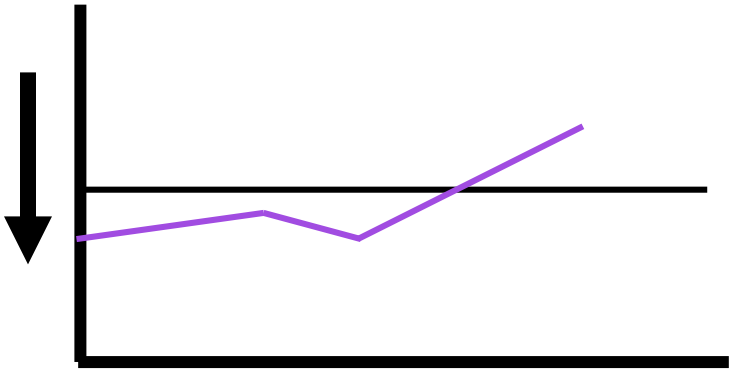


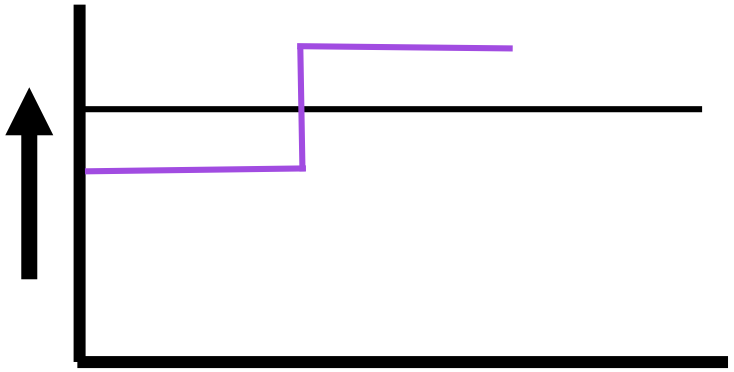
Size



Weight



Power



Performance

Anybody can optimize one TPM… what is the right set for your system?

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Cost as a TPM?

- Arguments **for**
  - Systems Engineers must be sensitive to cost in all decisions, trades, and analyses
  - Affordability is one of the “ilities” in the INCOSE SE Handbook
  - Cost needs to be a “first class citizen” along with technical (e.g., CAIV – cost as an independent variable)
- Arguments **against**
  - What part of “technical” do you not understand?
  - TPMs should focus on key performance requirements that drive the system architecture and design
  - Cost is important, but is not a TPM – we have the “ility” of Affordability to deal with that

Cost as a TPM Discussion

- An effective systems engineer always considers cost
- However, it is important to discuss what “type” of cost we are talking about:
  - Typically, other people are concerned with
    - **research and development (R&D) costs and capital** - project managers and department heads
    - **production costs and capital** - the factory manager
    - **target product cost** - marketing/business development/sales
    - **Total Ownership Cost (TOC)** – customer/purchaser
  - It falls on the systems engineer to own the **life cycle cost (LCC)**
- Whether you decide to include cost as a TPM or keep it separate, be sure to include LCC as part of your trade-off studies

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Wrap-up/Summary

- Differences in opinion exist in any vibrant and evolving community – Systems Engineering is no exception
- Usually, each philosophical opinion has some merit or truth in it
- As with most Systems Engineering discussions, “it depends” plays into the answer
- One of our goals as excellent Systems Engineers is to find the right “balance” amongst the different positions, depending upon the particular context or circumstances

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Comments?
Other Philosophical Questions?

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