Maps or Itineraries?

A Systems Engineering Insight from Ancient Navigators

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Abstract

Processes and procedures are the prominent heart of most detail descriptions of Systems Engineering. The "Systems Engineering Process", the "Vee Diagram", ISO 15288, the INCOSE SE Handbook, and enterprise-specific business process models all appear to focus attention on process and procedure when we want to "get specific" about doing systems engineering.

But, there is another, entirely non-procedural, way to view systems engineering, even in a highly detailed context. This approach is to describe the information configuration space that is "navigated" by systems engineering projects, building an understanding of what is meant by project trajectories in that space. While this may sound abstract, that is mostly because we have lacked the explicit maps necessary to describe this configuration space. We understand concrete steps of a procedure, so we focus on that. But, where do these steps take us? And, what does "where" mean in this context?

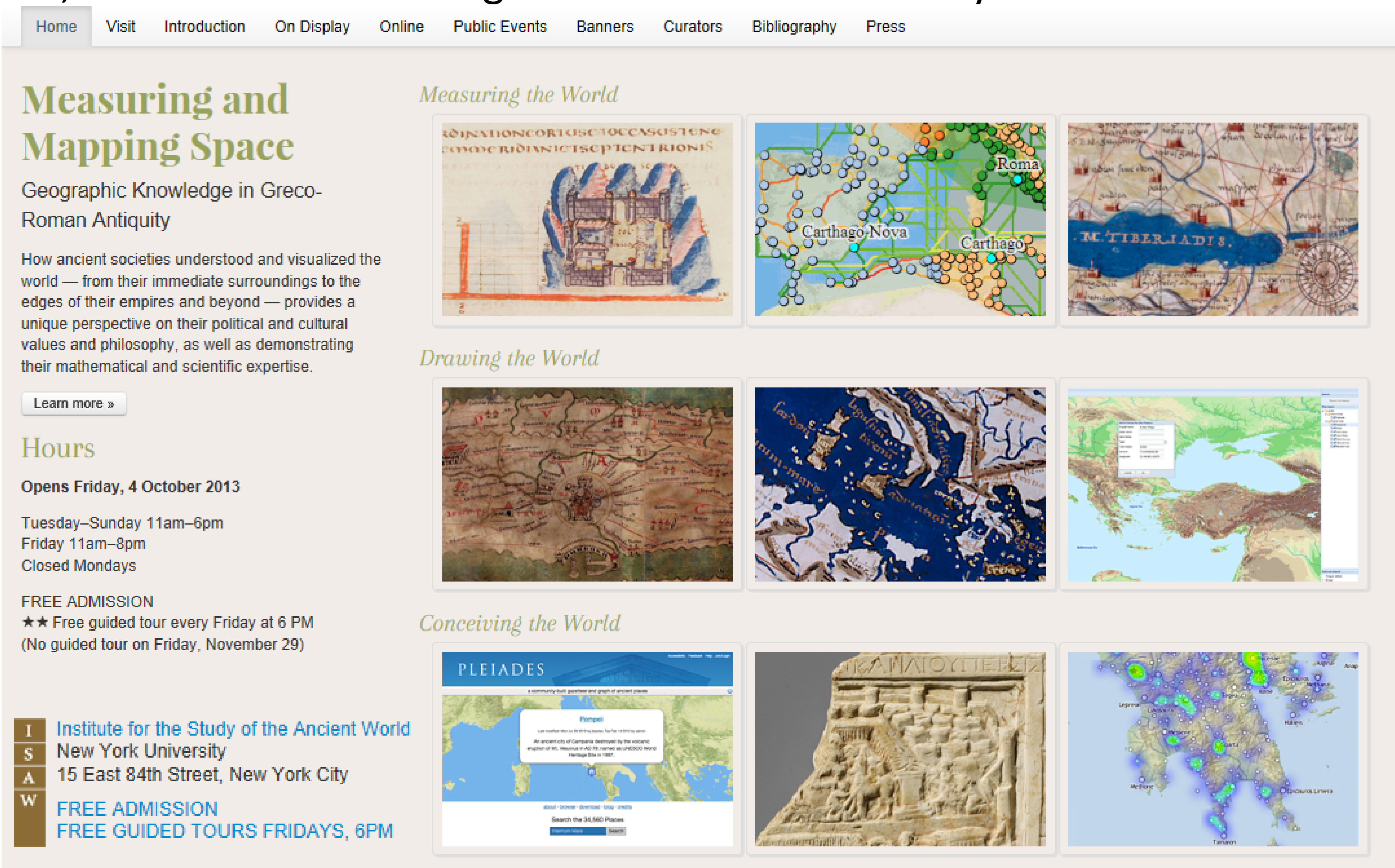
The implied transition in understanding and performing innovation in general, and systems engineering in particular, can improve critical thinking, sometimes distracted by procedure. Innovation is under intense competitive pressure to increase its performance. To better understand where we are headed, it is helpful to consult a recent discovery about ancient navigators, who apparently operated by itineraries before maps were available. This presentation will review what anthropologists have discovered about that history, and connect it to the current and future states of systems engineering.

For those who perform or lead systems engineering and innovation, this perspective has been found to improve ability to accomplish their real goals more effectively, while better understanding both traditional and emerging approaches to their underlying processes.

Contents

Maps and Itineraries of Ancient Navigators

- Scholars[4,5] suggest that ancient (Greco-Roman) navigators did not possess the "ancient maps" attributed to them—they were produced in later ages!
- So, what did ancient navigators use to find their way?



http://isaw.nyu.edu/exhibitions/space/index.html

From: “A World Without Maps”

- *Wall Street Journal,* 10.30.2013
- The exhibition at the Institute for the Study of the Ancient World
- It demonstrates that what we think of as “ancient maps” were created long after the period in which we assume they were used, so the reviewer asks . . .

*“Why do we have **virtually no ancient maps of the ancient world**? After all, sailors, traders and soldiers had to find their way around. The show's curator, Roberta Casagrande-Kim, distinguishes between a **map** and an **itinerary**. The latter ‘must have existed aplenty, but being strictly functional probably deteriorated through overuse,’ she says. ‘**A map, however small its focus, suggests a kind of implicit overview**, and that is the show's subject.’”* *(emphases added)*

THE WALL STREET JOURNAL.

ARTS & ENTERTAINMENT

A World Without Maps

By MELIK KAYLAN

Oct. 29, 2013 4:42 p.m. ET

Measuring and Mapping Space: Geographic Knowledge in Greco-Roman Antiquity

Institute for the Study Of the Ancient World
Through Jan. 5

Ptolemy's Earth, from a Florentine manuscript (c. 1460). *New York Public Library*

New York

The contradiction may seem insuperable—that the main point of an exhibition about ancient maps is that there weren't any, or any that have survived. But don't let that put you off. The show at the Institute for the Study of the Ancient World (ISAW) is titled "Measuring and Mapping Space: Geographic Knowledge in Greco-Roman Antiquity." Its explanatory circular tells of focusing on "ancient cartography and the ways in which Greek and Roman societies perceived and represented both the known and unknown worlds." All of

Itineraries are not Maps

- “Greeks and Romans usually employed what are known as <u>*periploi*</u> (‘coastal navigations’), which <u>*listed*</u> ports and landmarks to facilitate commercial and military sailing, and <u>*itineraria*</u> (“journeys”), <u>*lists*</u> of locations and distances based on land routes.”
  - from: “Measuring and Mapping Space: Geographic Knowledge in Greco-Roman Antiquity” (NYU ISAW)

Itinerary ≠ Map!

(What am I doing?) *(Where am I?)*

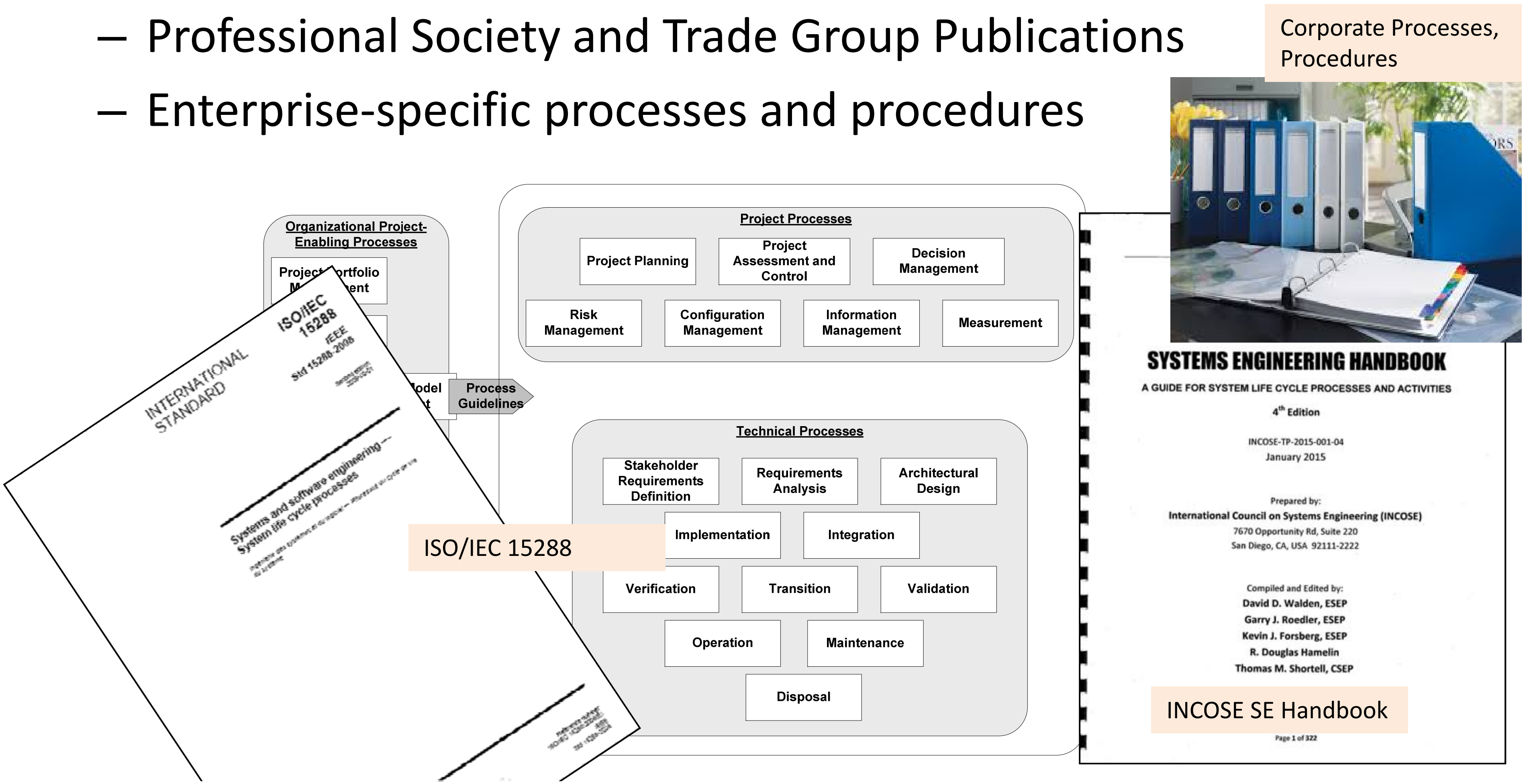
When they eventually did emerge, maps represented a newer idea of the nature of “where”.

Maps and Itineraries of the Systems Engineer

- Systems Engineers must "navigate" a different type of "journey"—a *project*:
  - More complex and abstract than physical travel
  - But, it still has a starting point and a destination
  - With opportunities to become lost or disoriented
  - With risks of not reaching the desired destination
- Is this more than just a metaphorical comparison?
  - Yes: We will argue that it can be much more!

Maps and Itineraries of the Systems Engineer

- Systems Engineers have plenty of "itineraries" to guide their work, in the form of processes and procedures:
  - International Standards
  - Professional Society and Trade Group Publications
  - Enterprise-specific processes and procedures



Maps and Itineraries of the Systems Engineer

- Have you ever witnessed this problem?
  - The junior engineer says he has done all the steps.
  - All the checklist boxes are checked.
  - But the result is not acceptable.

Maps and Itineraries of the Systems Engineer

- It is clear what an SE Itinerary is, but what is an SE map?
  - SE Map: is not a list of SE tasks. Descriptions of systems work (Vee diagrams, ISO/IEC 15288, INCOSE SE Handbook, enterprise business procedures, etc.) are closer to itineraries than to maps.
  - SE Map: is not a model of the process--ancient mariners where not traveling through “step space”, but through *geographic space*.
  - A geographic map describes *where* we really want to end up, along with key relationships around it, in 1, 2, or 3 dimensions (degrees of freedom in geographic space), and *where* we are along the way.
  - Knowing steps we have performed does not guarantee “location” (dead reckoning).
  - So, what is an “SE Map”?

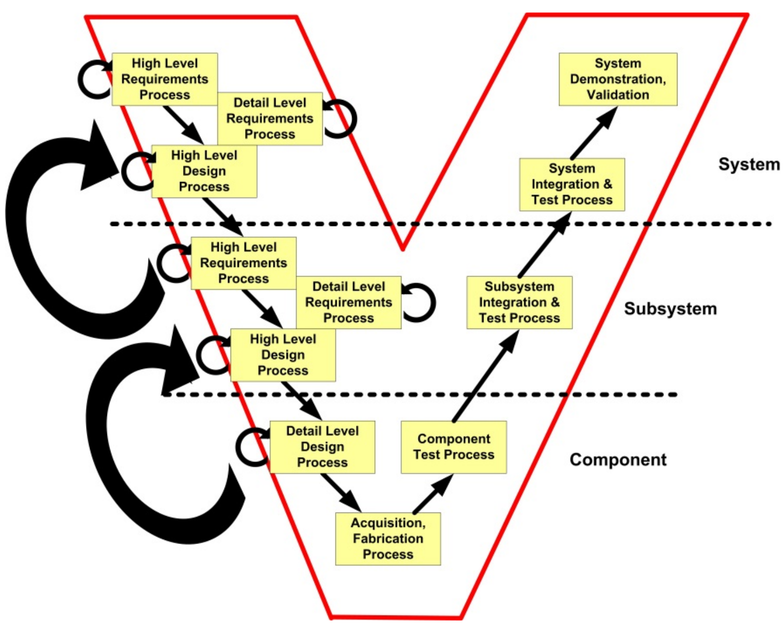
Itinerary ≠ Map!

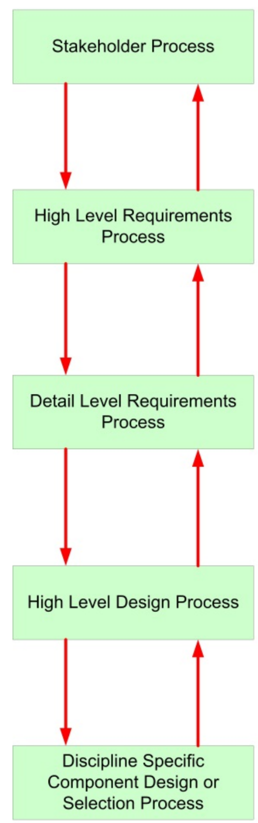
(What should I do?)

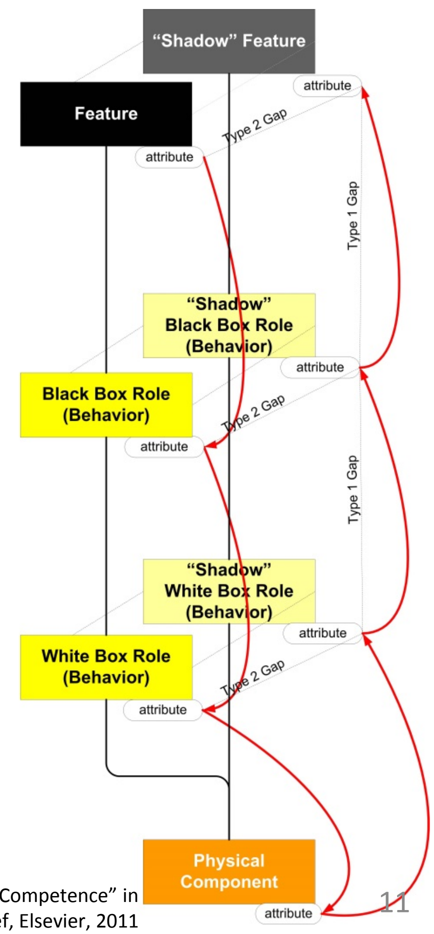
(Where am I?)

(Where am I going?)

- A <u>practical</u> connection is this --
  - Since the innovation cycle is inherently iterative, ...
  - How do we know when we are "done"?
  - It is not by knowing what steps we have completed, ...
  - It is by knowing how "close" our current configuration is to the "destination" we are seeking.
  - The distance metrics are in <u>*information space*</u>.





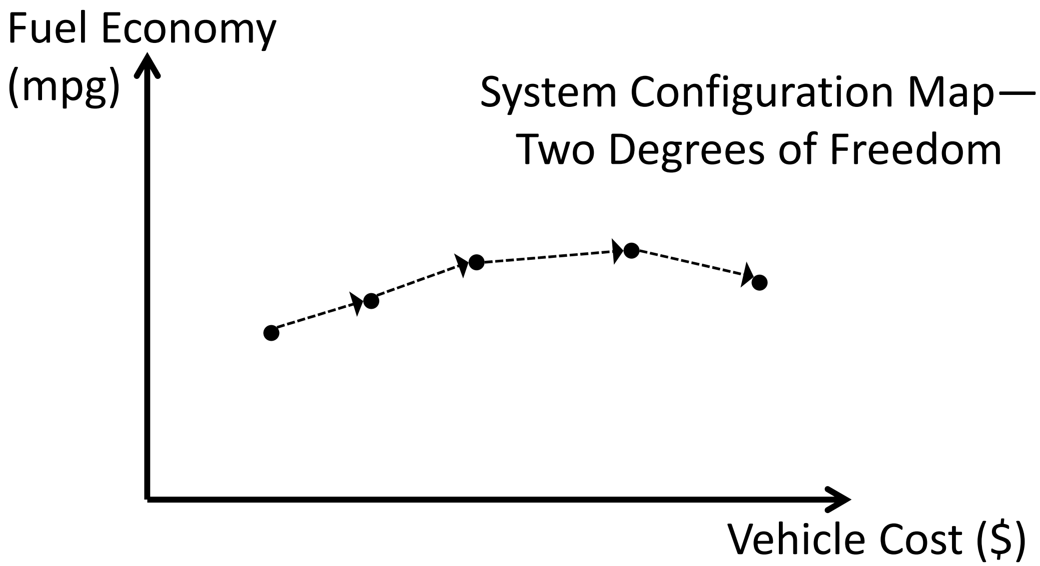


From: W. Schindel, "Innovation as Emergence: Hybrid Agent Enablers for Evolutionary Competence" in *Complex Adaptive Systems, Volume 1*, Cihan H. Dagli, Editor in Chief, Elsevier, 2011

Maps and Itineraries of the Systems Engineer

- The work of engineering is performed on, and produces, information.
- A map appropriate to this territory would be a map about information—not the steps of a procedure (the itinerary).
- We know one kind of “map about information”: an information model (i.e., E-R model)
- The hard sciences (laws) provide the underlying relationship map for physics, chemistry, etc. This is why their related engineering practices (mechanical, electrical, chemical engineering) are able to navigate more generally.
- Imagine trying to learn chemistry by studying the process of cooking instead of studying the materials in process!
- The SE Map describes the information space of possible places to be, good and not good, and how they are related to each other.
- Early “systems engineering” itineraries (still dominant!) are not maps through the information navigated by those procedures.
- As we begin making real information model maps of the information, there are many startling and valuable discoveries.

Simple Example of a Trajectory on a System Map: Two Degrees of Freedom



- Of course, we'd likely add many more degrees of freedom (weight, range, etc.)—so system maps will tend to be high dimension, and subject to "slicing" into multiple views.
- During innovation / development cycles, and some life cycles, the "current configuration" may involve sets of ranges or lists, instead of individual points, so the trajectory becomes an ordered series of envelopes.

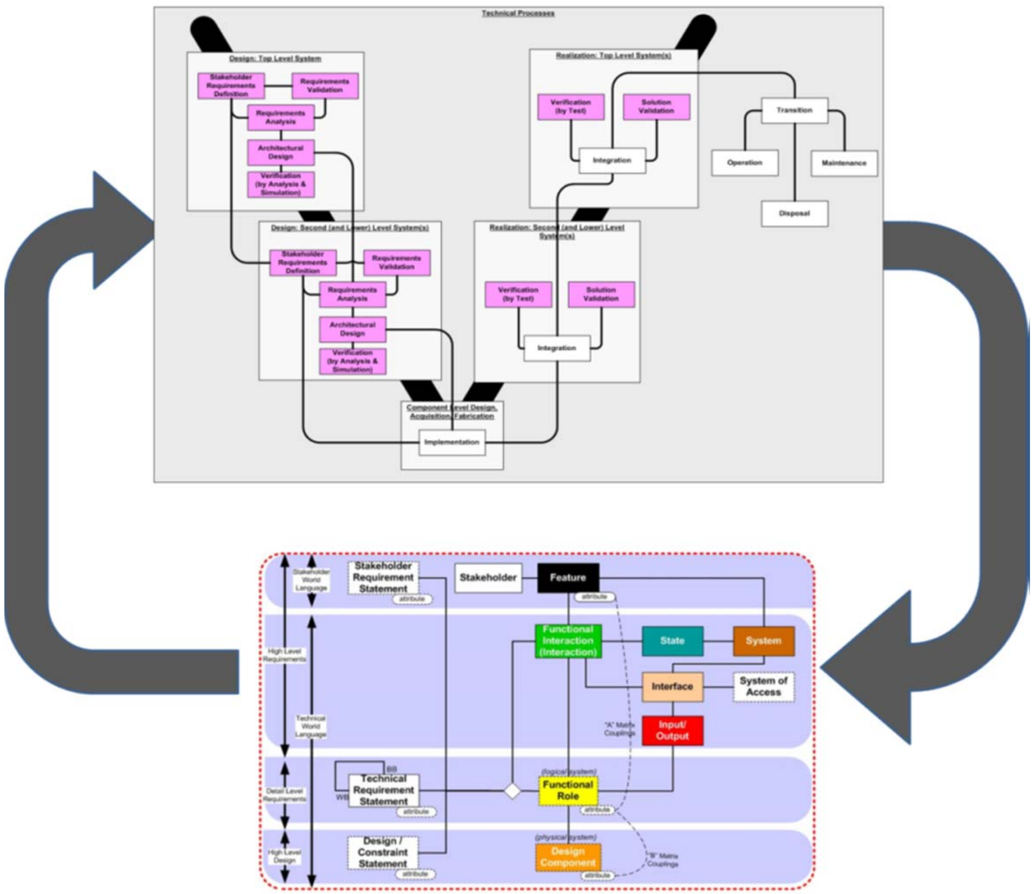
Moving to Real Semantic Models of Systems

- "System Space" is the multi-dimensional space, in which each "point" represents one possible configuration of a system of interest.
- A "path" through this space is a set of system configurations, "visited" as the configuration of the (modeled) system is changed.
- The different degrees of freedom of this space are related to each other, by a system model.
- Such a system model may be expressed using a system modeling language, such as SysML, covering enough variables and relationships to describe the system for SE purposes.
- Model-Based Systems Engineering (MBSE) is growing in popularity, but procedure is still the dominant way people think about systems engineering, even with model-based artifacts, but this is shifting . . .

Moving to Real Semantic Models of Systems

A start is to view the engineering model as what passes through the engineering process, in a series of transformations:

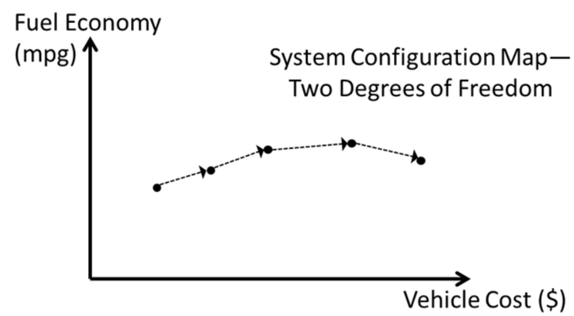
Innovation Process



Information Passing Through the Innovation Process

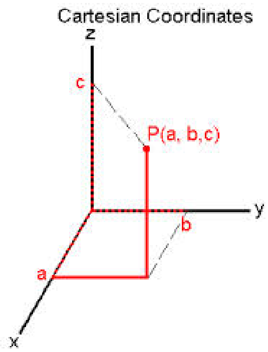
<u>SE Process</u>: For example, modeled as ISO15288 process areas.

<u>Trajectory</u> as a series of system configurations, through iterations of the SE process:



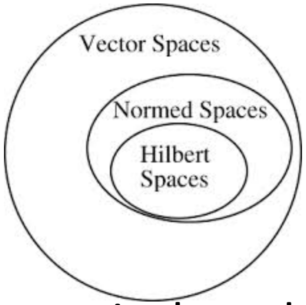
System Space: The Geometrization of System Models

- Such a geometric shift in thinking (about spaces of systems) is reminiscent of earlier geometric shifts in human thinking:
  – Geometrization of algebra, by Rene Descartes (“Cartesian” coordinates):



Rene Descartes
1596 - 1650

- As system models also add modeling of (infinite dimensional) behavior, Hilbert Space (David Hilbert) provided the next required generalization, supporting a geometrical view of mathematical function:



David Hilbert
1862 - 1943

- Geometrization of mathematical models does not ultimately mean drawing geometric diagrams (as in 2D & 3D geographic maps), but instead provides geometry-based intuitive basis for more abstract mathematical operations: distance (metric spaces), projections, inner products, paths in configuration space.

- What are the degrees of freedom (variables) needed by System Models?
  - System modeling languages (SysML, OPM, IDEF, etc.) have progressed; however . . .
  - At least some thought leaders agree that these models are more syntactical than semantic, with none of them currently a complete semantic model of the subject systems.
  - Too big and too small at the same time.
  - What is the Smallest Model of a System?

What Is the Smallest Model of a System?

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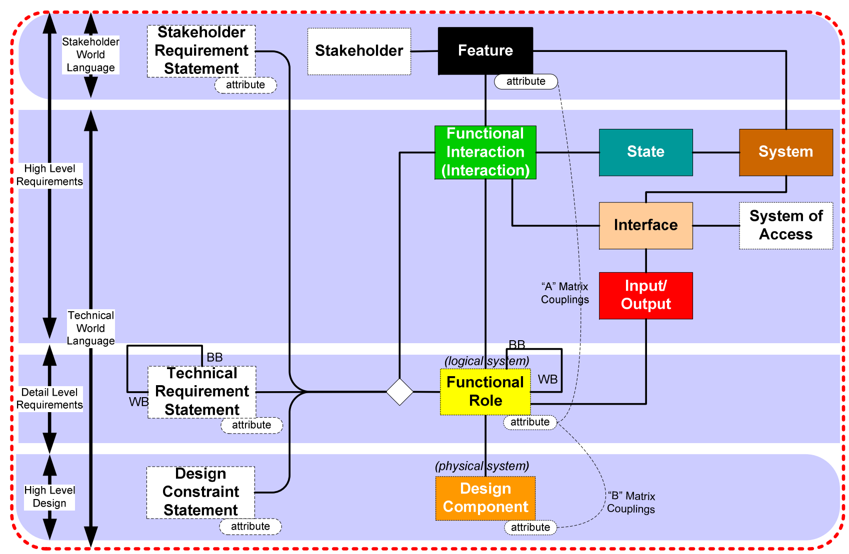
Abstract. How we represent systems is fundamental to the history of mathematics, science, and engineering. Model-based engineering methods shift the nature of representation of systems from historical prose forms to explicit data structures more directly comparable to those of science and mathematics. However, using models does not guarantee simpler representation--indeed a typical fear voiced about models is that they may be too complex.

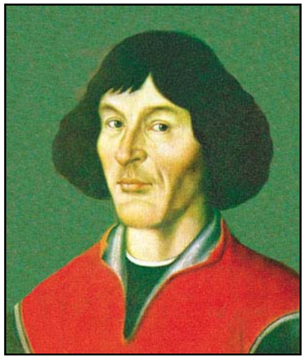
Minimality of system representations is of both theoretical and practical interest. The mathematical and scientific interest is that the size of a system's "minimal representation" is one definition of its complexity. The practical engineering interest is that the size and redundancy of engineering specifications challenge the effectiveness of systems engineering processes. INCOSE thought leaders have asked how systems work can be made 10:1 simpler to attract a 10:1 larger global community of practitioners. And so, we ask: What is the smallest model of a system?

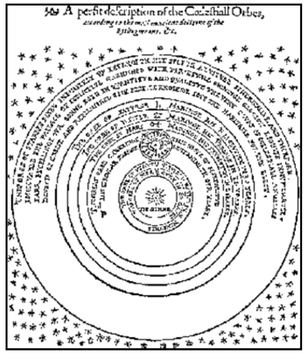


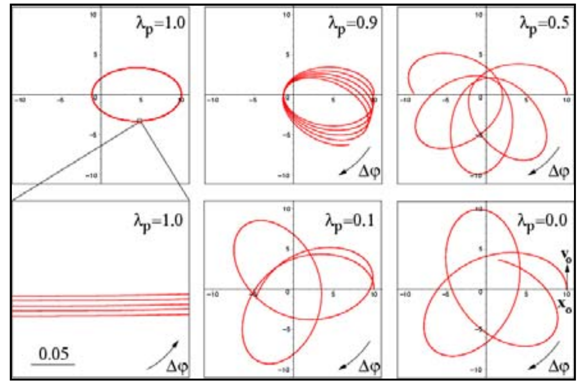
Moving to Real Semantic Models of Systems

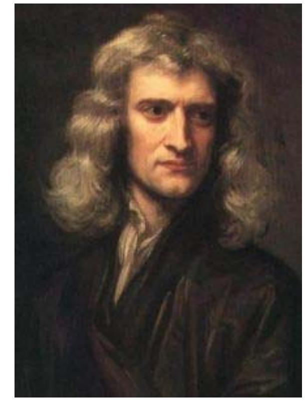
- Why is such a transition in thought important?
  - Because of what happened in science, engineering & mathematics after the relationships were discovered and become explicit.
  - Relational clues from the history of physical sciences.
  - Prime example: the central role of physical interactions as the basis of all scientific law.
- INCOSE Vision 2025 envisions this kind of progress
- But first, models of systems must achieve some improvement to their foundations:
  - Stronger semantic metamodel in MBSE.
  - Difference between modeling business process information about systems and views, versus modeling the systems themselves, in tradition of science.

So what? *Maps are more than just pictures*.





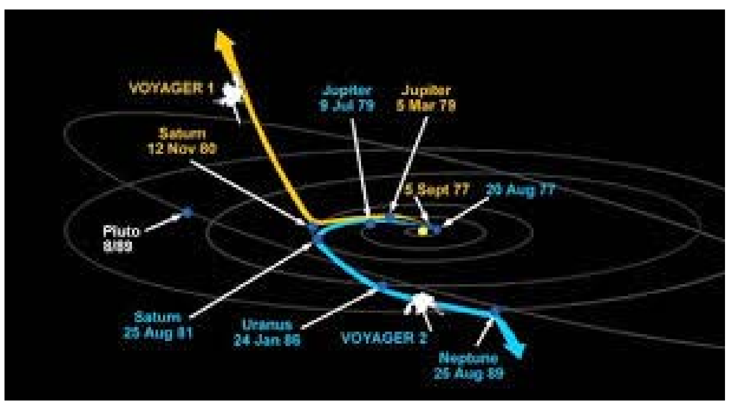




Nicolas Copernicus 1473-1543

Isaac Newton 1643-1727

- Progressively building & refining simplest explanatory models, the core function of science, creates our understanding of the universe and ability to live and interact better within it.
- What will improved models of generalized systems bring?



Voyager 1 and 2 launched 1977, explored all the giant outer planets of our solar system, 48 of their moons, and the unique systems of rings and magnetic fields those planets possess.

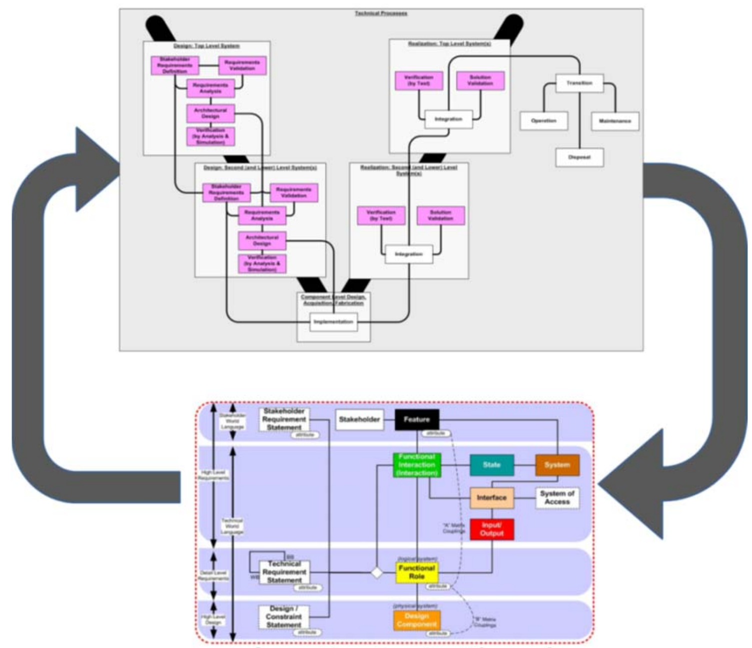
Memory, Persistence: Importance of Roads Already Traveled to Innovation

- System configuration trajectories are not just important during development of a single generation of system:
  - Across the life cycles of multiple systems, we have the evolution system that emerge from their environments
  - What is the configuration space for evolving systems across life cycles?
- Two other GLRC2014 sessions:
  - Patterns in science and patterns in engineered systems
  - The general System of Innovation Pattern in nature and human-made world.
  - Patterns, as the basis for engineered platforms and product lines, become the equivalent of theories in science.
  - Patterns as (financially capitalizable) software
  - Genes as patterns
- Session to occur at IW2015 MBSE Workshop:
  - Modeling Agile Systems and Agile Systems Modeling

Implications for Systems Engineering

1. Current procedure-based systems engineering & innovation processes can be made more effective by increasing the focus on underlying information vs. procedure, with these impacts:
    - Simplify, while Speeding and Improving Outcomes
    - Improved ability to understand and communicate current situation
    - More general Risk Management
    - Increased agility
2. This has allowed us to create an MBSE-based version of 15288 Systems Engineering, using models and patterns.
3. Improved natural roles for automated aids, modelling tools, PLM systems:
    - Example: Use of gap views, especially at Stakeholder Feature level
    - Realizing INCOSE Vision 2025

Innovation Process



Information Passing Through the Innovation Process

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Speaker

Bill Schindel is president of ICTT System Sciences (www.ictt.com), a systems engineering company.

His 40-year engineering career began in mil/aero systems with IBM Federal Systems, Owego, NY, included service as a faculty member of Rose-Hulman Institute of Technology, and founding of three commercial systems-based enterprises.

He has led and consulted on improvement of engineering processes within automotive, medical/health care, manufacturing, telecommunications, aerospace, and consumer products businesses.

Schindel earned the BS and MS in Mathematics. At the 2005 INCOSE International Symposium, he was recognized as the author of the outstanding paper on Modeling and Tools, co-led a 2013 research project on the science of Systems of Innovation within the INCOSE System Science Working Group, and currently co-leads the Patterns Challenge Team of the OMG/INCOSE MBSE Initiative.

Bill is an INCOSE CSEP, and president of the Crossroads of America INCOSE chapter.