Systems Engineering Principles and the Challenges in Deriving Them

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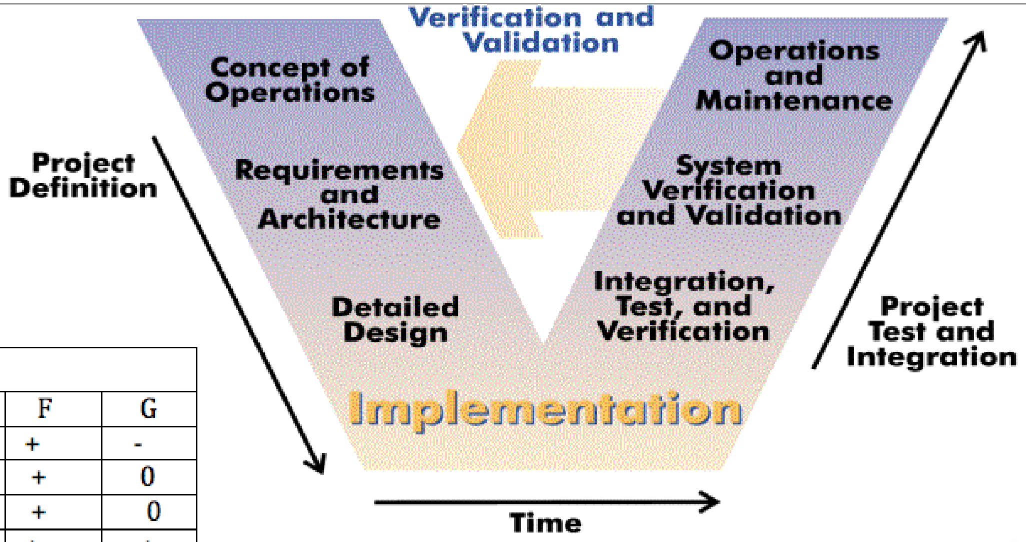
Don’t we already have SE Principles?

What is the Basis?

	Concepts						
Criteria	A	B	C	D	E	F	G
Cost	-	+	-	0	+	+	-
Effectiveness	-	+	+	+	+	+	0
Speed	-	0	-	+	+	+	0
Portability	+	+	+	+	+	+	+
Mani ability	0	+	-	+	+	+	0
Total Weight	-2	4	-1	4	5	5	0

Concepts: A= Telescopic Net Catcher
B= Football with sensors
C=Drone Football Catcher
D= 3D Moving Automatic Football Catcher
E= 2D Moving Automatic Football Catcher
F= Glowing Football with LED’s
G=Pivoting /Collapsing Net Catcher



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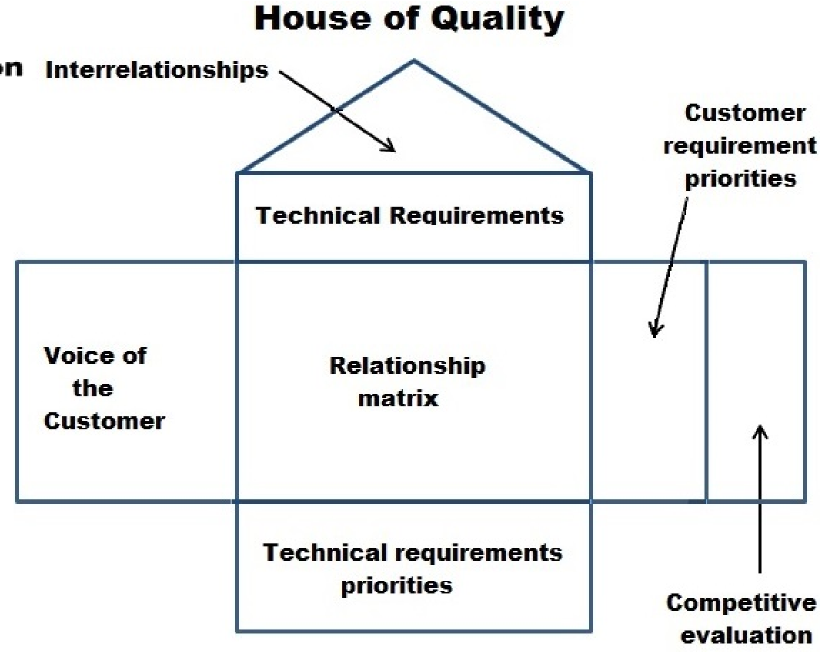
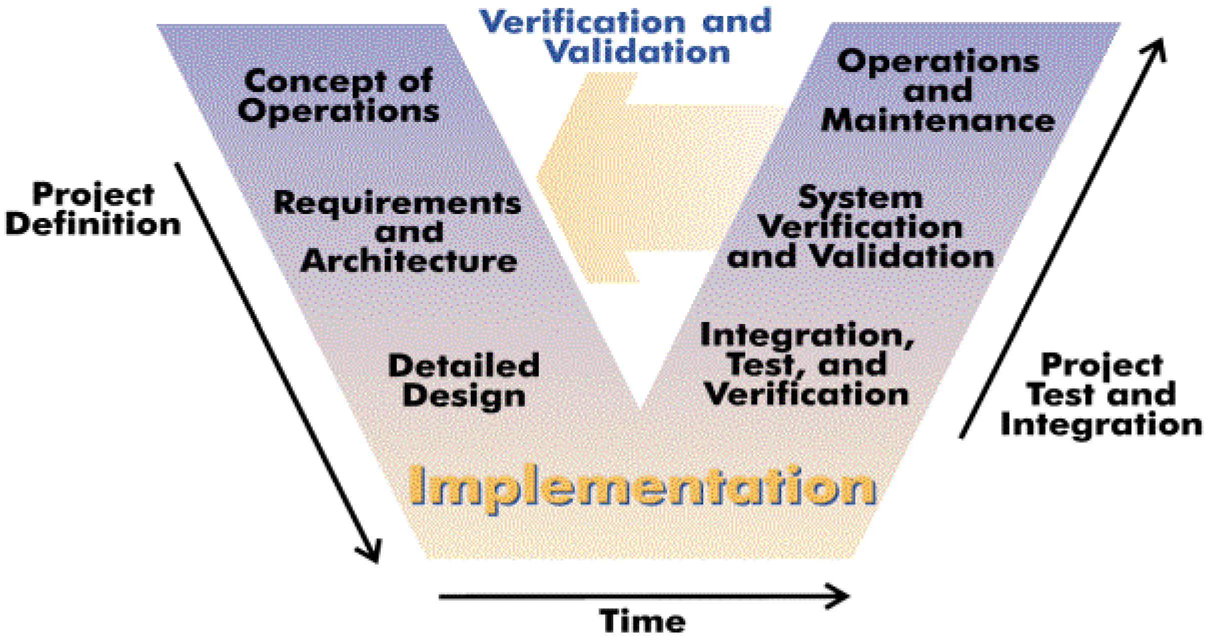


Don’t we already have SE Principles?

Rules of Thumb

“We’ve always done it this way”

But is it the RIGHT way?



Hold up, Principle or Theory?

Theory - A coherent group of propositions formulated to explain a group of facts or phenomena in the natural world and repeatedly confirmed through experiment or observation

Principle - A fundamental truth or proposition that serves as the foundation for a system of belief or behaviour or for a chain of reasoning.

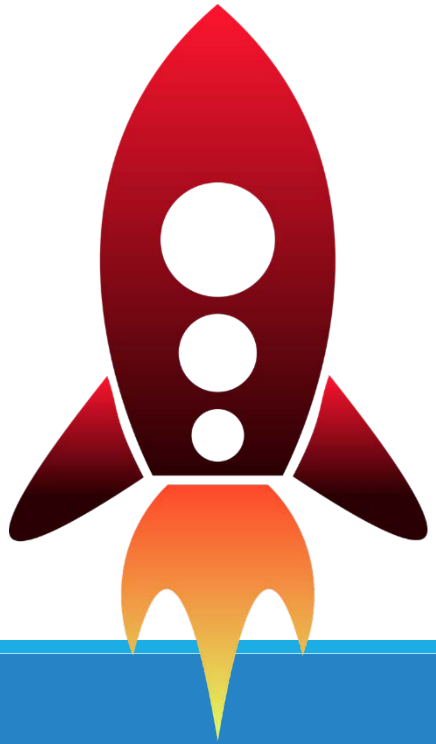
For our purposes – A theory supports a principle.

Where do we start? Maybe with Theory?

Could form a unified SE theory

Could form a SE theory based on a collection of other theories

- SE based on a middle range set of theories



We are not there yet, need to start higher

Need to understand what a theory would ground.

Need Principles.

Lack of theory common in beginning of fields

Heuristics is common practice in fields that are just getting their footing

Experiment and try things out

Before understanding, in depth, why it works

Many optimization algorithms have heuristically determined parameters

Maybe, one day, a theory would explain how to determine

So Lets Start with Principles

Establish knowledge

Identify if existing theories support

Eventually we will get to a theory (ies) of Systems Engineering

Taking Action

In 2018 INCOSE established Systems Engineering Principles Action Team

Task: Form a foundation for SE through a set of guiding principles

- Borrow from previous studies
- Modify existing principles
- Form new principles

What is a principle?

Accepted truths that apply throughout a discipline

Criteria:

Transcends lifecycle	Not a how statement
Transcends system types	Informs a world view on SE
Transcends context	Focused, concise, clear
Supported by literature or widely accepted in profession (proven)	

The Team

Starting Place

NASA Systems Engineering Research Consortium Prior Work

- 7 Postulates (Assumed without proof to be true, real, or necessary)
- 12 Principles (Accepted truth which apply throughout the discipline)
- 4 Hypotheses (Believed can be proven/disproven through research)

Systems Principles work by:

- Old Dominion
- INCOSE
- University of Adelaide
- Centre of Systems Philosophy
- Etc.

What was the Process?

Monthly Phone Calls

Face 2 Face – December 2018

What was the Process?

Monthly Phone Calls

Define Scope

Define Principle

Literature Reviews

Settle on starting with NASA Consortium Postulates and Principles

What was the Process?

Go through each NASA Consortium Postulate and Principle

Edit a document as a group word for word

Obtain consensus on principles

Face 2 Face – December 2018

Challenges faced by Team

Definition for Principle

- Keep postulates?
- Theory?

Evidence for principles

- Consistently struggled with quality of evidence to support principles
- Industry “how its done” vs. academic “what supports it”
- Across fields (System Science, Optimization, etc.) the amount of evidence to support a principle differs

Challenges faced by Team

Language of Principles

- Certain words have different meanings in different fields (Constraint, Stakeholder, Preference)

Principle Ownership

- Certain principles and their language were championed by individuals
- Were important to a specific field
- Ex. “Modeling of systems must account for system interactions and couplings”
- Ex. “Systems engineering decisions are made under uncertainty accounting for risk”

BUT

Without the diversity the principles would be:

- Biased towards a field
- Biased towards a sector
- Difficult to be accepted by community

Product

Starting from the NASA Consortium:

- 7 postulates
- 12 principles
- 4 Hypotheses

The Principle Action Team settled on:

- 0 Postulates
- 15 Principles
- 3 Hypotheses

Product

Principle 1: Systems engineering in application is specific to stakeholder needs, solution space, resulting system solution(s), and context throughout the system life cycle.

Principle 2: Systems engineering has a holistic system view that includes the system elements and the interactions amongst themselves, the enabling systems, and the system environment

Product

Principle 3: Systems engineering influences and is influenced by internal and external resource, political, economic, social, technological, environmental, and legal factors

Principle 4: Both Policy and Law must be properly understood to not overly constrain or under constrain the system implementation

Product

Principle 5: The real physical system is the perfect representation of the system

Principle 6: A focus of systems engineering is a progressively deeper understanding of the interactions, sensitivities, and behaviors of the system, stakeholder needs, and its operational environment

Product

Sub-Principle 6(a): Mission context is defined based on the understanding of the stakeholder needs and constraints

Sub-Principle 6(b): Requirements and models reflect the understanding of the system

Sub-Principle 6(c): Requirements are specific, agreed to preferences within the developing organization

Product

Sub-Principle 6(d): Requirements and system design are progressively elaborated as the development progresses

Sub-Principle 6(e): Modeling of systems must account for system interactions and couplings

Sub-Principle 6(f): Systems engineering achieves an understanding of all the system functions and interactions in the operational environment

Product

Sub-Principle 6(g): Systems engineering achieves an understanding of the system's value to the system stakeholders

Sub-Principle 6(h): Understanding of the system degrades during operations if system understanding is not maintained.

Product

Principle 7: Stakeholder needs can change and must be accounted for over the system life cycle.

Principle 8: Systems engineering addresses stakeholder needs taking into consideration budget, schedule, technical, and other expectations and constraints

Sub-Principle 8(a): Systems engineering seeks a best balance of functions and interactions within the system budget, schedule, technical, and other expectations and constraints.

Product

Principle 9: Systems engineering decisions are made under uncertainty accounting for risk

Principle 10: Decision quality depends on knowledge of the system, enabling system(s), and interoperating system(s) present in the decision-making process

Principle 11: Systems engineering spans the entire system life-cycle

Product

Sub-Principle 11(a): Systems engineering obtains an understanding of the system

Sub-Principle 11(b): Systems engineering defines the mission context (system application)

Sub-Principle 11(c): Systems engineering models the system

Product

Sub-Principle 11(d): Systems engineering designs and analyzes the system

Sub-Principle 11(e): Systems engineering tests the system

Sub-Principle 11(f): Systems engineering supports the production of the system

Sub-Principle 11(g): Systems engineering supports operations, maintenance, and retirement

Product

Principle 12: Complex systems are engineered by complex organizations

Principle 13: Systems engineering integrates engineering disciplines in an effective manner

Principle 14: Systems engineering is responsible for managing the discipline interactions within the organization

Product

Principle 15: Systems engineering is informed by a broad set of theories and heuristics

Sub-Principle 15(a): Systems engineering has a systems theory basis

Sub-Principle 15(b): Systems engineering has a physical/logical basis specific to the system

Sub-Principle 15(c): Systems engineering has a mathematical basis

Product

Sub-Principle 15(d): Systems engineering has a sociological basis specific to the organization

Product

Hypothesis 1: If a solution exists for a specific context, then there exists at least one ideal Systems Engineering solution for that specific context

Hypothesis 2: System complexity is greater than or equal to the ideal system complexity necessary to fulfill all system outputs

Product

Hypothesis 3: Key Stakeholders preferences can be represented mathematically

Next Steps

Adoption by INCOSE

Presentations for wider acceptance

Modifications if needed

Questions?