SYSTEMS ARCHITECTING
A RECIPE FOR SUCCESS

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INCOSE
International
Symposium
2022

Syntell | excellence in systems lifecycle management

AGENDA

WHAT is Architecture and Systems Architecting?

WHY is it important?

HOW is it done?

WHERE to find more information?

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WHAT IS A SYSTEM ARCHITECTURE?

> *"The fundamental organisation of a system, embodied in its components, their relationships to each other and to the environment, and the principles governing its design and evolution."*
>
> *Systems and Software Engineering - Architecture Descriptions (ISO/IEC/IEEE 42010:2011)*

- ## Components and their relationship
  - ### System elements with interfaces
- ## Governing Principles
  - ### Architecture styles

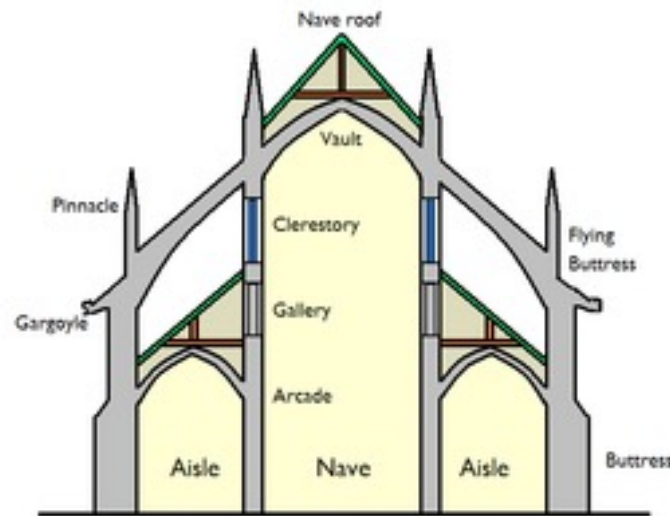**Figure 4: Different architectural styles in dwellings**

Source: INCOSE UK, Introduction to System Architecting, 2019

WHAT MAKES A GOOD ARCHITECTURE?

- *Utilitas* – functionality, usefulness
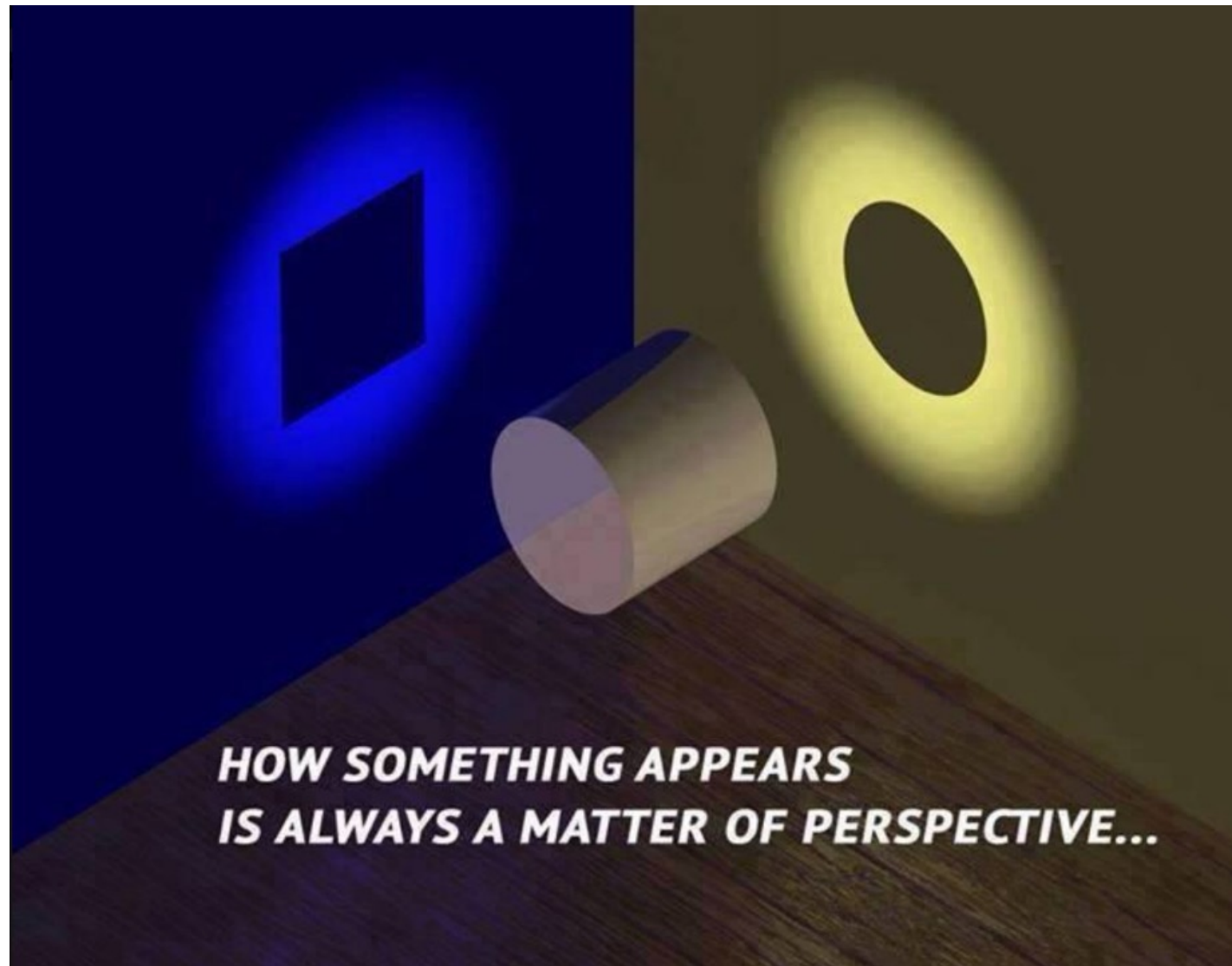- *Firmitas* – strength, robustness
- *Venustas* – aesthetics and beauty

Vitruvius (Roman architect and engineer, 1st century BC)
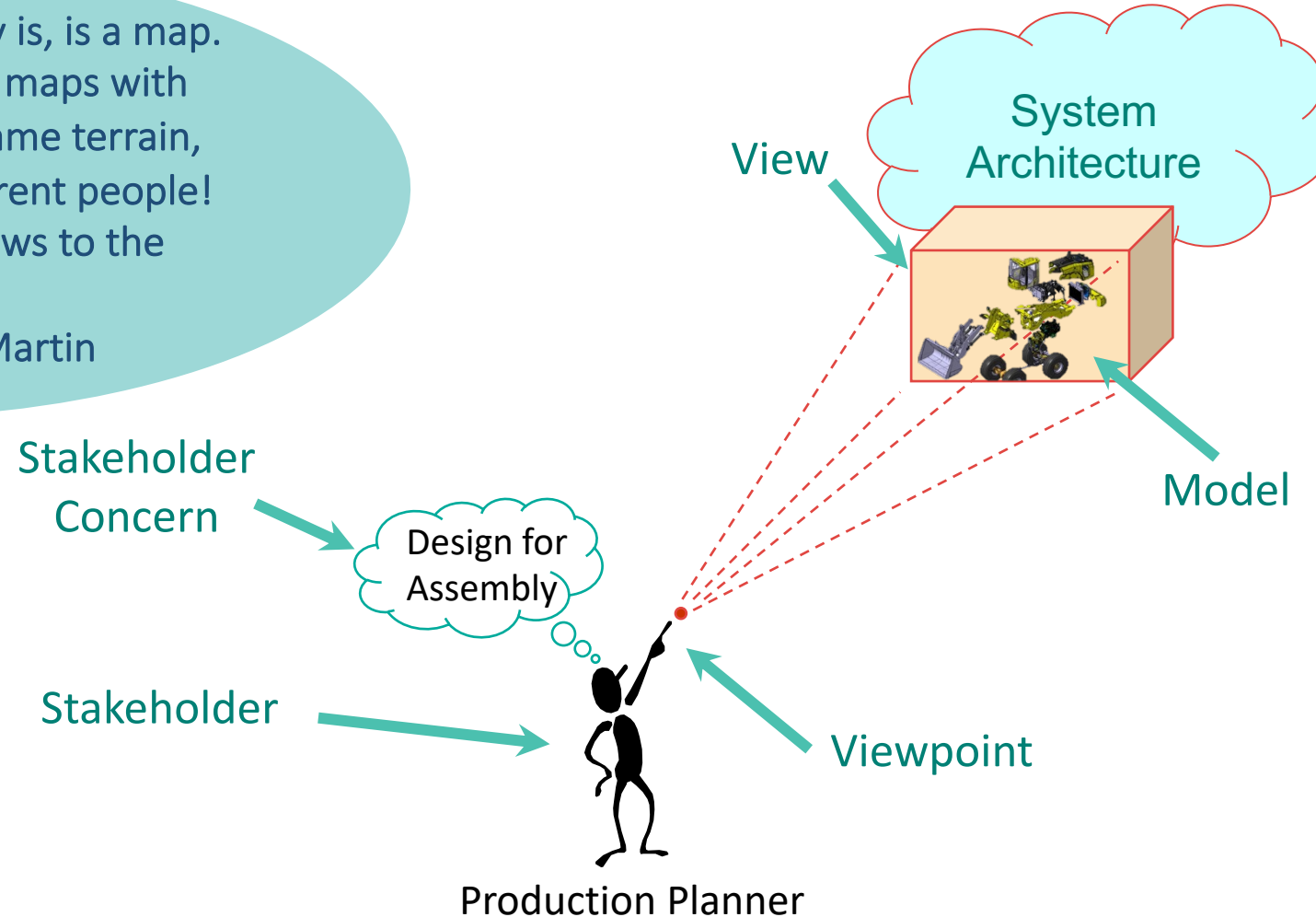
Gothic architecture style

SYSTEM ARCHITECTURE – THERE IS MORE TO IT!

HOW SOMETHING APPEARS
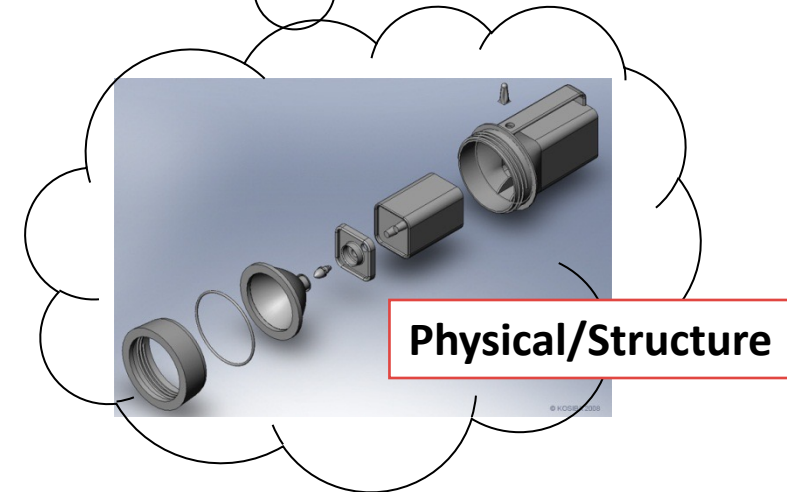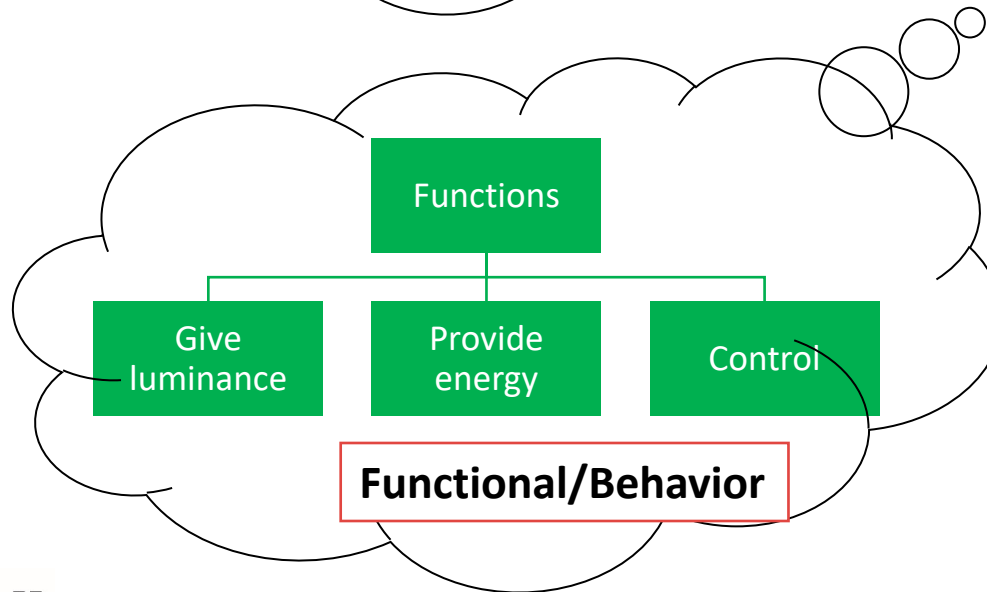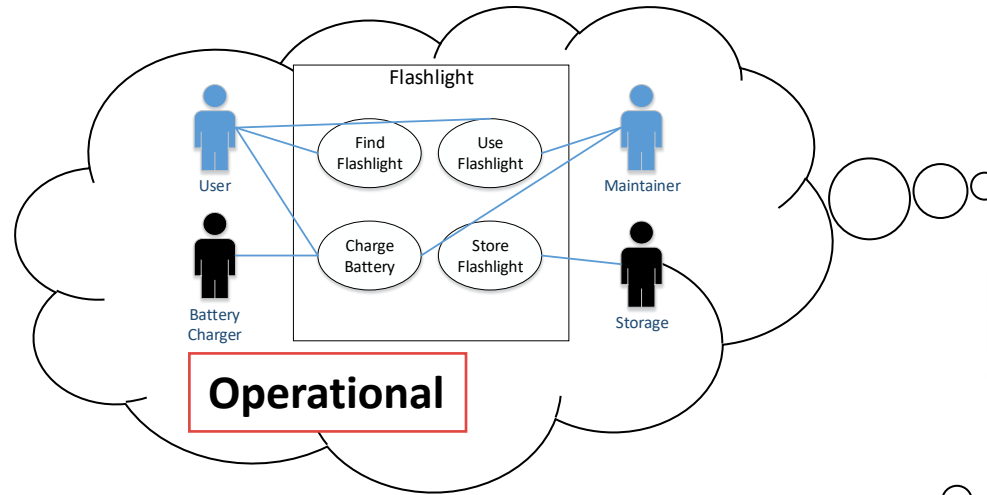IS ALWAYS A MATTER OF PERSPECTIVE...

VIEWING THE SYSTEM ARCHITECTURE

"What architecture basically is, is a map. But different people want maps with different details. It is the same terrain, but different maps for different people! You have to tailor the views to the audience".

James N. Martin

View

System Architecture

Model

Stakeholder Concern

Design for Assembly

Stakeholder

Viewpoint

Production Planner

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
BASIC ARCHITECTURE VIEWS USED IN SE

Operational

Flashlight
- User
- Maintainer
- Battery Charger
- Storage
- Find Flashlight
- Use Flashlight
- Charge Battery
- Store Flashlight

Functional/Behavior

- Functions
  - Give luminance
  - Provide energy
  - Control

Physical/Structure

ARCHITECTURE VIEWS PUT IN A FRAMEWORK

LAYER OF ABSTRACTION		PILLAR			
		REQUIREMENTS	BEHAVIOR	STRUCTURE	PARAMETRICS
	BLACK BOX	Stakeholder Needs	Use Cases	System Context	Measurements of Effectiveness
	WHITE BOX	System Requirements	Functional Analysis	Logical Subsystems Communication	
	SOLUTION	Component Requirements	Component Behavior	Component Assembly	Component Parameters

Source: https://discover.3ds.com/sites/default/files/2021-12/magicgrid-book-of-knowledge-ebook.pdf (latest version)

UNIFIED ARCHITECTURE FRAMEWORK (UAF)

- Enterprise Framework that includes system views

- Rows: Viewpoints
- Columns: Aspects
- Cell: Aspect-oriented view with metamodel

- Benefit: consistency among models
- Challenge: selecting a minimum but enough views

	Taxonomy Tx	Structure Sr	Connectivity Cn	Processes Pr	States St	Interaction Scenarios Is	Information If	Parameters Pm	Constraints Ct	Roadmap Rm	Traceability Tr
Metadata Md	Metadata Taxonomy Md-Tx	Architecture Viewpoints [a] Md-Sr	Metadata Connectivity Md-Cn	Metadata Processes [a] Md-Pr	-	-			Metadata Constraints [a] Md-Ct		Metadata Traceability Md-Tr
Strategic St	Strategic Taxonomy St-Tx	Strategic Structure St-Sr	Strategic Connectivity St-Cn	-	Strategic States St-St	-			Strategic Constraints St-Ct	Strategic Deployment, St-Rm / Strategic Phasing St-Rm	Strategic Traceability St-Tr
Operational Op	Operational Taxonomy Op-Tx	Operational Structure Op-Sr	Operational Connectivity Op-Cn	Operational Processes Op-Pr	Operational States Op-St	Operational Interaction Scenarios Op-Is	Conceptual Data Model,	Environment Pm-En	Operational Constraints Op-Ct	-	-
Services Sv	Service Taxonomy Sv-Tx	Service Structure Sv-Sr	Service Connectivity Sv-Cn	Service Processes Sv-Pr	Service States Sv-St	Service Interaction Scenarios Sv-Is			Service Constraints Sv-Ct	Service Roadmap Sv-Rm	Service Traceability Sv-Tr
Personnel Pr	Personnel Taxonomy Pr-Tx	Personnel Structure Pr-Sr	Personnel Connectivity Pr-Cn	Personnel Processes Pr-Pr	Personnel States Pr-St	Personnel Interaction Scenarios Pr-Is	Logical Data Model,		Competence, Drivers, Performance Pr-Ct	Personnel Availability, Personnel Evolution, Personnel Forecast Pr-Rm	Personnel Traceability Pr-Tr
Res...				Resource Processes ...Pr	Resource States Rs-St	Resource Interaction Scenarios Rs-Is	Physical schema, real world results	Measurements Pm-Me	Resource Constraints Rs-Ct	Resource evolution, Resource forecast Rs-Rm	Resource Traceability Rs-Tr
					-	-			Security Constraints Sc-Ct	-	-
									-	Project Roadmap Pj-Rm	Project Traceability Pj-Tr
				-	-				-	Standards Roadmap Sr-Rm	Standards Traceability Sr-Tr
Actuals Resources Ar		Actual Resources Structure, Ar-Sr	Actual Resources Connectivity, Ar-Cn	Simulation [b]					Parametric Execution/ Evaluation [b]	-	-

Choose wisely based on the questions you want answers to!

Dictionary * Dc
Summary & Overview SmOv
Requirements Rq

https://www.omgwiki.org/uaf/doku.php#uaf_gridinformation_vs_presentation
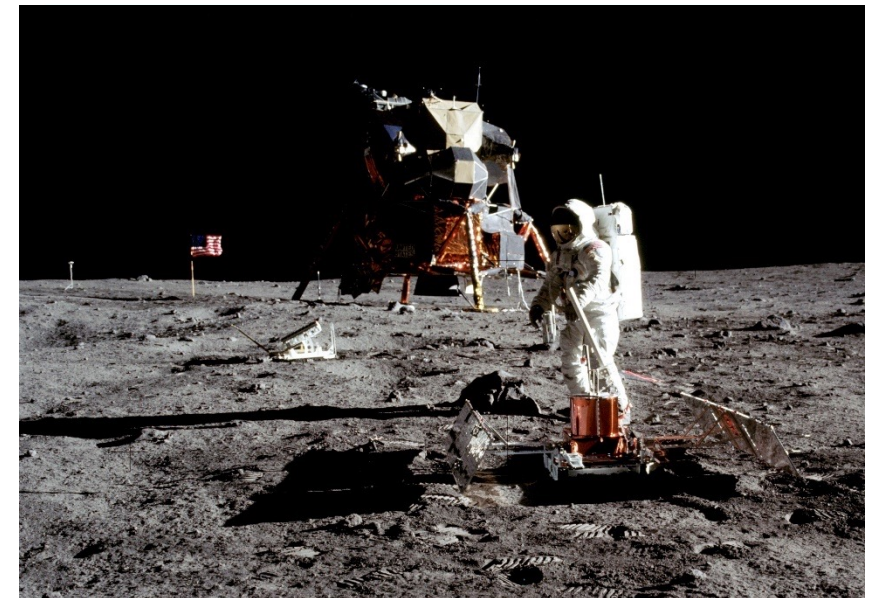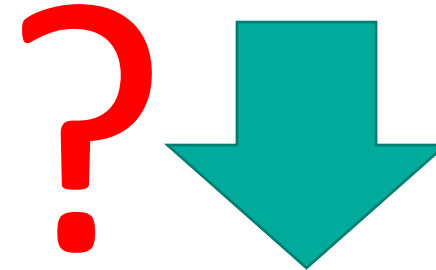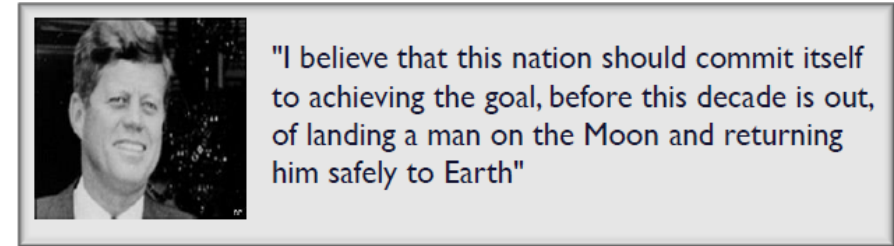
WHAT IS SYSTEMS ARCHITECTING?

- Characterize the problem space and determine suitable solutions
- Describe or document an architecture
- Communicate the architecture descriptions
- Evaluate and certifying proper implementation
- Maintain and improving an architecture

ISO/IEC/IEEE 42020:2019 – Architecture Processes
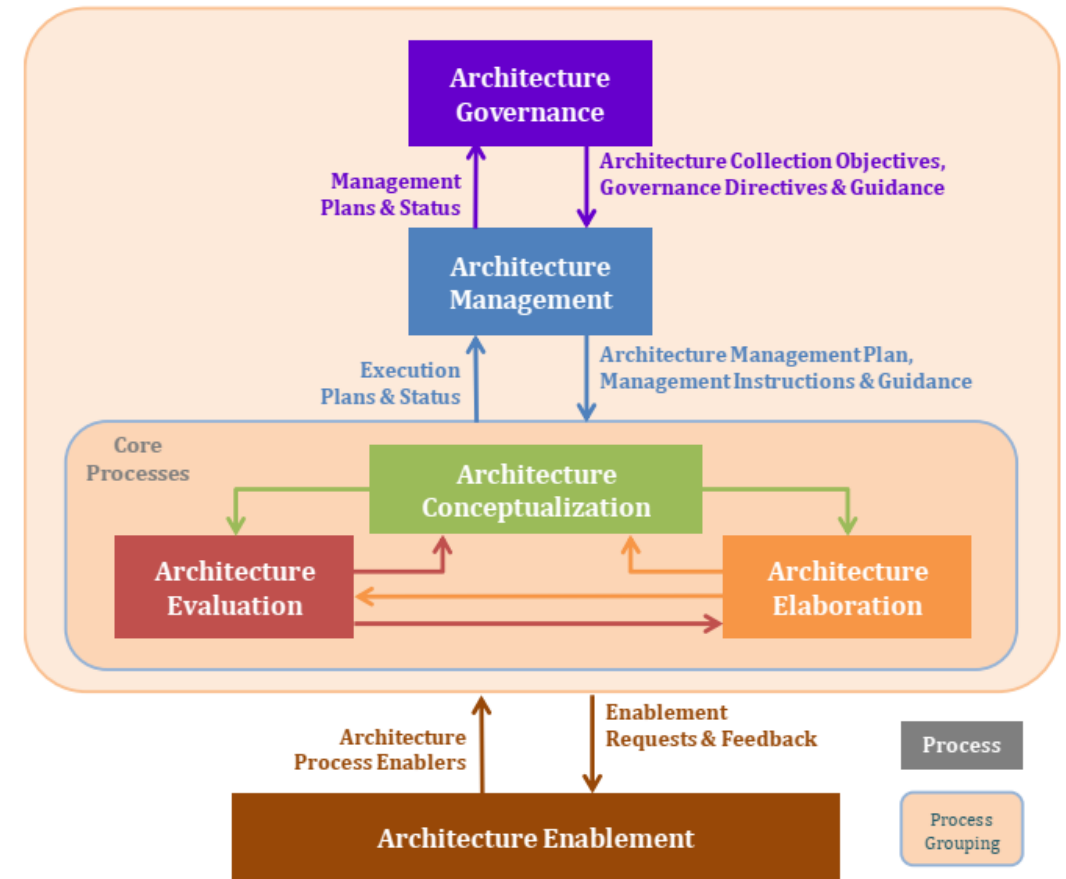
WHY IS SYSTEMS ARCHITECTING IMPORTANT?

- Manage complexity
  - Abstraction that explains complexity without omitting relevant details
  - used for communication between stakeholders and/or analysis
- Define system elements and ensure what is designed fit into the whole
- Facilitate PLE and Agile approaches
- Support finding new solutions
  - Using different viewpoints
  - Exploring the system context

"I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to Earth"

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FUNCTIONAL ARCHITECTURE VIEW SUPPORTS THINKING IN NEW WAYS

Move Load

Environment

Load

Resupply & Service

Ground
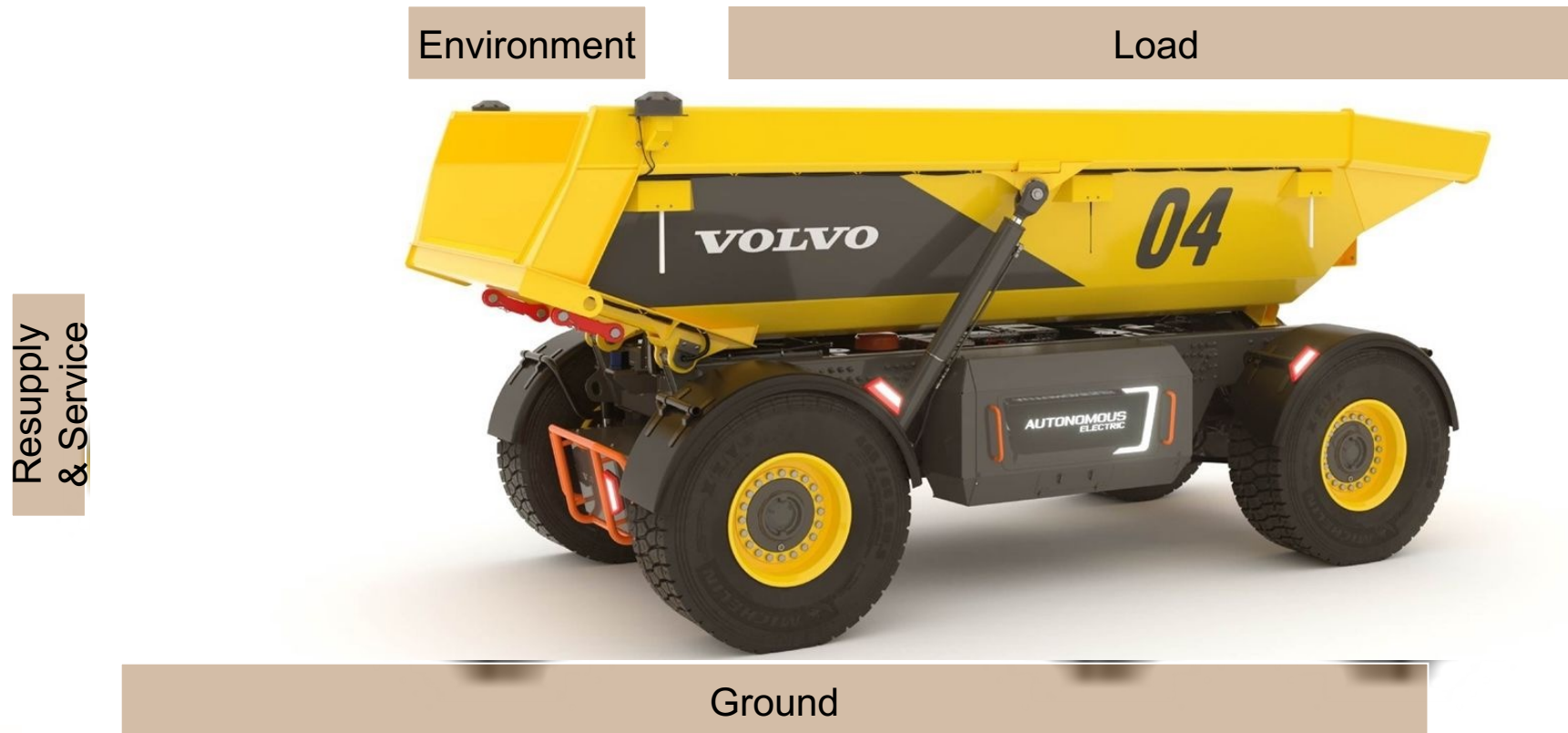
STEPPING UP ONE ARCHITECTURAL LEVEL

+

From Product to Service

HOW DO WE DO SYSTEMS ARCHITECTING?

- Architecture definition process according to SE Handbook
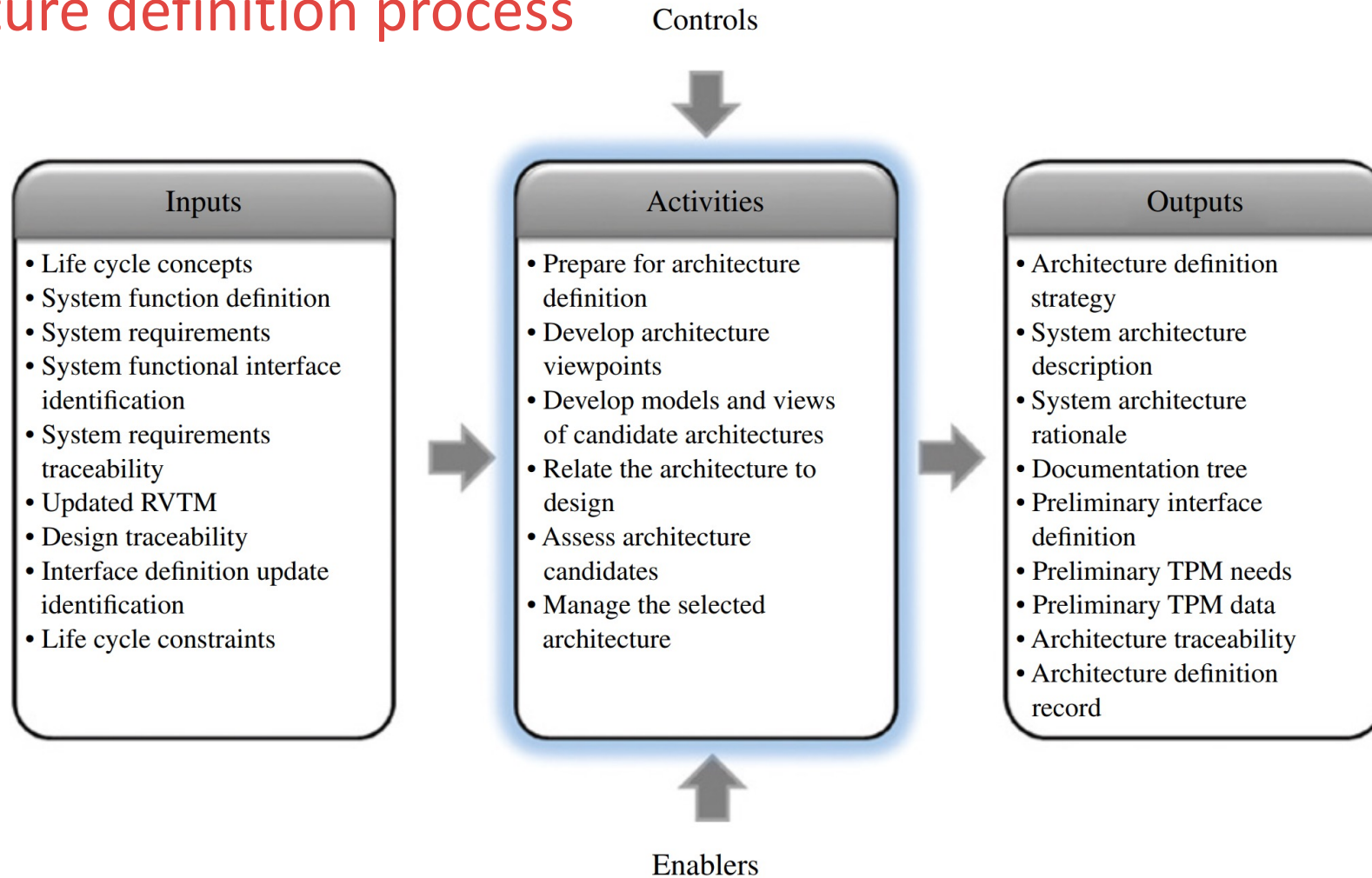- Architecture concept evaluation
  - Defining the alternatives
  - Selecting the right criteria

HOW DO WE DO SYSTEMS ARCHITECTING?
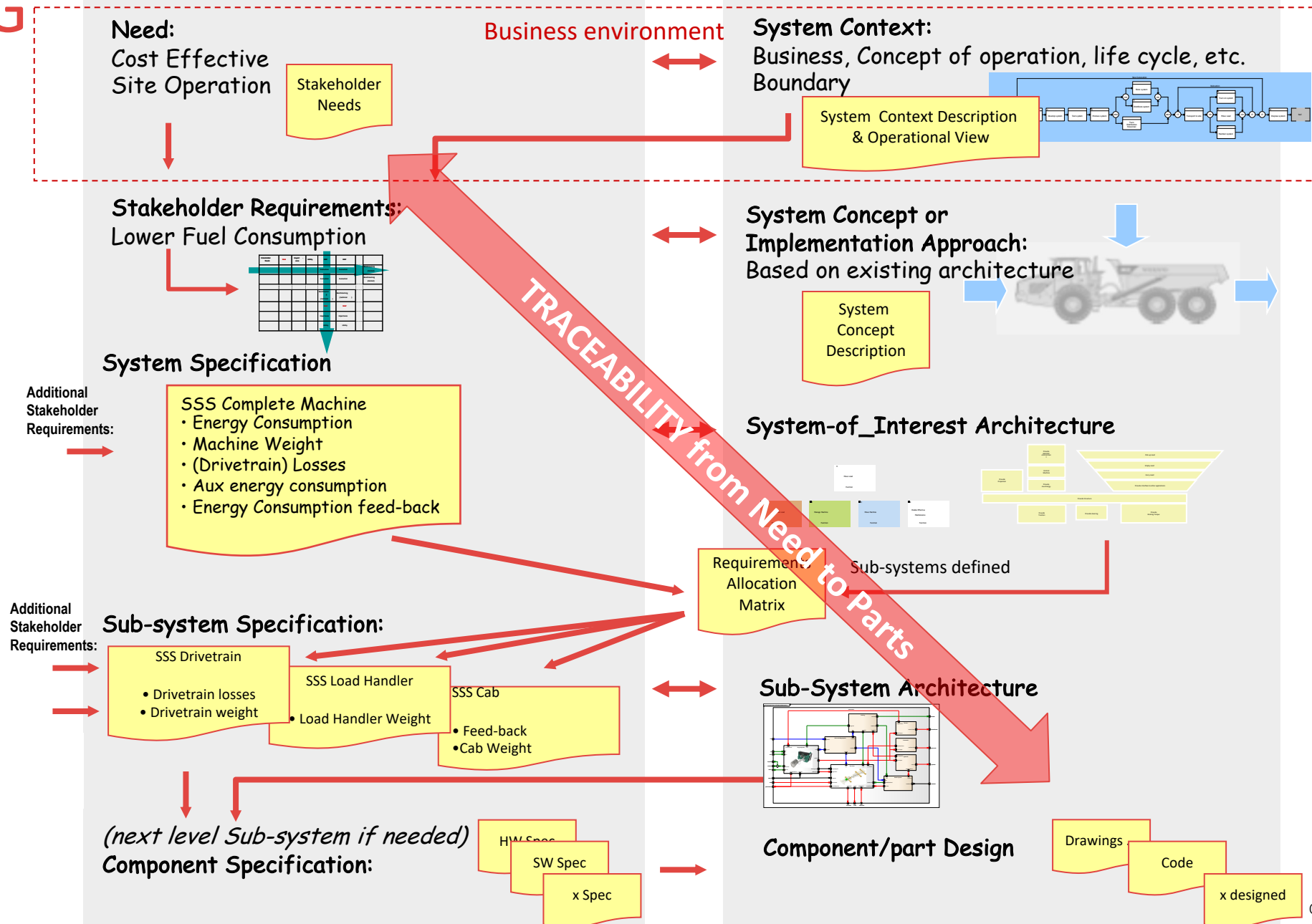
Architecture definition process

Controls

Inputs	Activities	Outputs
• Life cycle concepts • System function definition • System requirements • System functional interface identification • System requirements traceability • Updated RVTM • Design traceability • Interface definition update identification • Life cycle constraints	• Prepare for architecture definition • Develop architecture viewpoints • Develop models and views of candidate architectures • Relate the architecture to design • Assess architecture candidates • Manage the selected architecture	• Architecture definition strategy • System architecture description • System architecture rationale • Documentation tree • Preliminary interface definition • Preliminary TPM needs • Preliminary TPM data • Architecture traceability • Architecture definition record

Enablers

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CONCEPT SELECTION FUNNEL

Requirement
(need for solution)

Solution
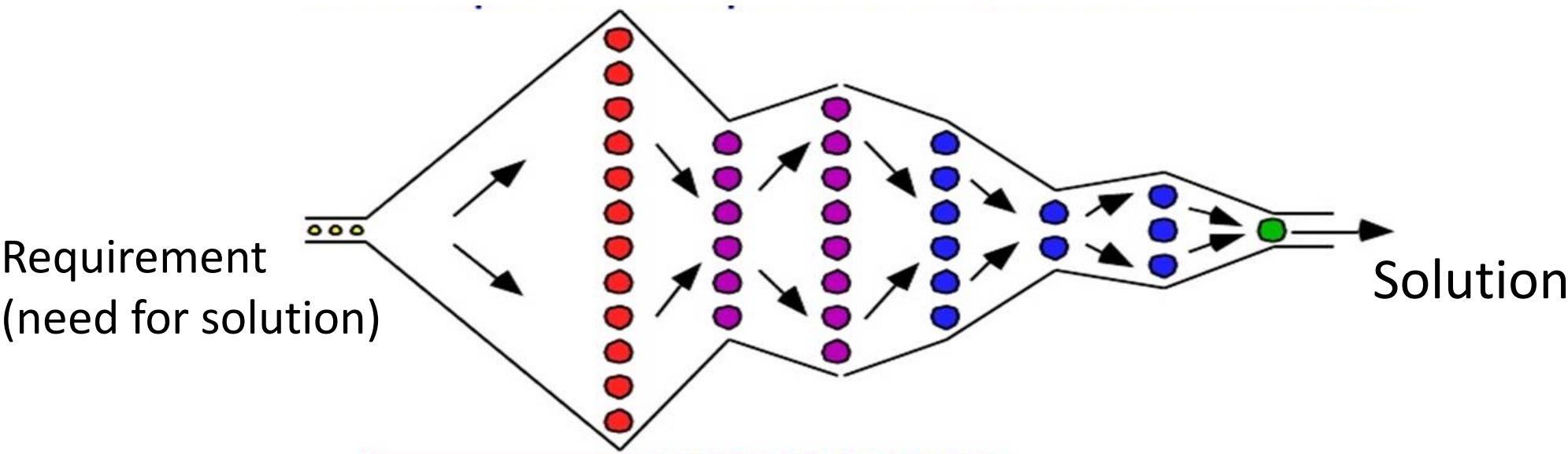
Concept identification

Concept evaluation

Concept selection

Karl T. Ulrich and Steven D. Eppinger, 2004, *Product Design and Development*, Exhibit 7-4, Chapter 7, 3rd Edition, Irwin McGraw-Hill

TENSIONS IN SELECTING ARCHITECTURE CONCEPT

Maneuverability

Producability

	Performance	
Function		Flexible manufacturing
System requirements		Strict process control
Performance specifications		Manage complexity
Human needs		Process revolution
Complexity		Tight integration
New technology	Fit	Product stability
Top down plan	Balance	Risk of overdesign
Conservative design	Compromise	Familiar technology
Continuous evolution		Bottom up implementation
Minimal interfacing		Simplicity
Avoid complexity		Affordability
Low level decisions		Strict acceptance criteria
Specialized manufacturing	Cost and Schedule	Environmental imperatives
		Form

Source: E. Rechtin, M Maier, The Art of Systems Architecting

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CONCEPT SELECTION

Understand the System Context → Architecture & Design

System definition

Define Needs and Requirements
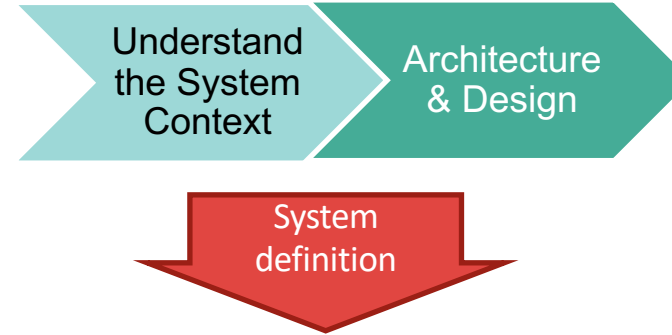
Business and Project Aspects

Criteria	Weight (1-5)	Reference (Current)	Alt. A Safety first	Alt. B Production	Alt. C Sales	Alt. D Engineering
Business						
ROI	4	S	-	S	++	-
Risk	2	S	++	S	--	-
Time to Market	5	S				S
Product						
Performance	3	S				++
Commonality	2	S				-
Flexibility	3	S				++
Compliance (Safety)	3	S	++	S	-	-
Organisational						
Strategic Fit	2	S	-	S	+	+
Lifecycle Management	4	S	S	-	-	-
WEIGHTED SCORE		0	-11	1	11	5
RANK		4	5	3	1	2

The level of effort setting it up and analyzing depends on importance of decision

Alternatives

Reference: https://www.burgehugheswalsh.co.uk/uploaded/1/documents/pugh-matrix-v1.1.pdf

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MODULAR ARCHITECTURE – THE USE OF N2/DSM
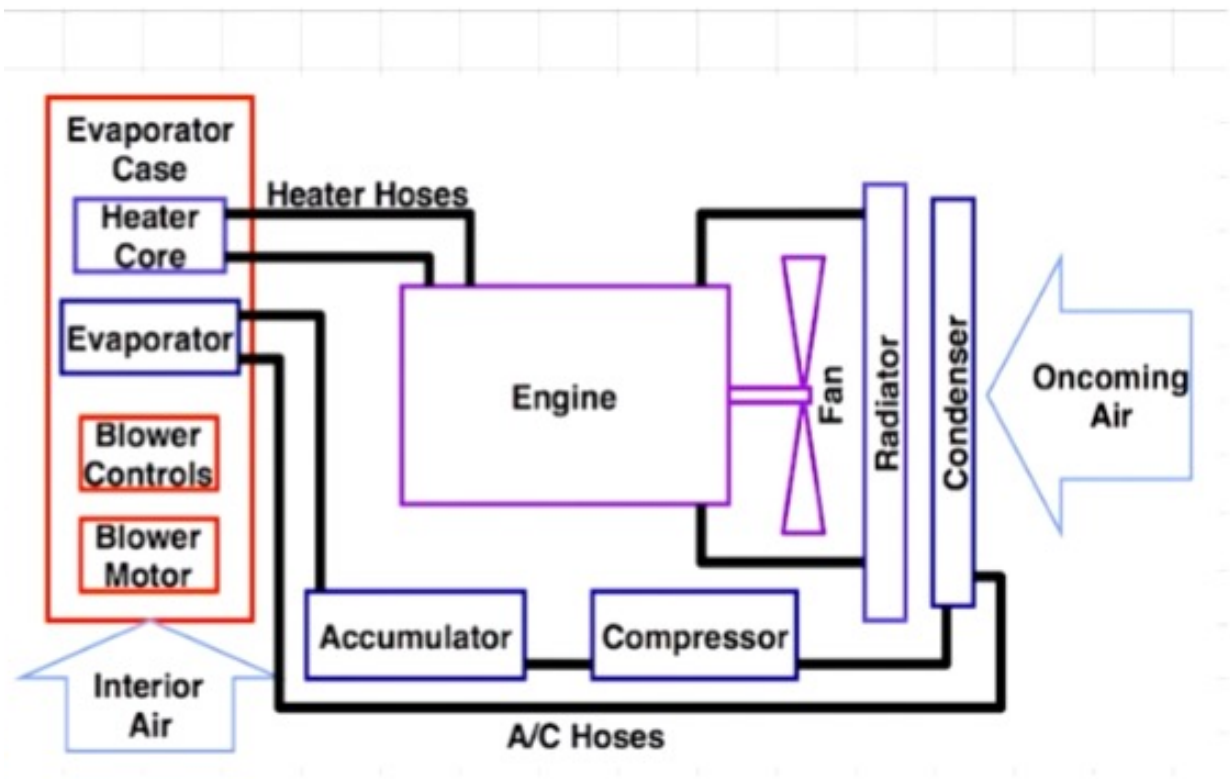
Climat Control System		F	G	J	M	C	A	D	E	B	L	K	H	I
Accumulator	F	F	x		x	x								
Compressor	G	x	G	x	x	A/C						x		
Condenser	J		x	J	x								x	x
A/C Hose	M	x	x	x	M	x	Blower							
Evaporator	C	x			x	C	x		x					
Evaporator Case	A					x	A	x	x	x				
Blower Controls	D						x	D	x					
Blower Motor	E						x	x	E			Heater		
Heater Core	B						x	x		B	x	x		
Heater Hoses	L									x	L	x		x
Engine	K		x							x	x	K	x	x
Fan	H			x								x	H	
Radiator	I			x							x	x		I

USE OF INTERFACE N2 MATRIX

Partitioning
(aka Clustering)
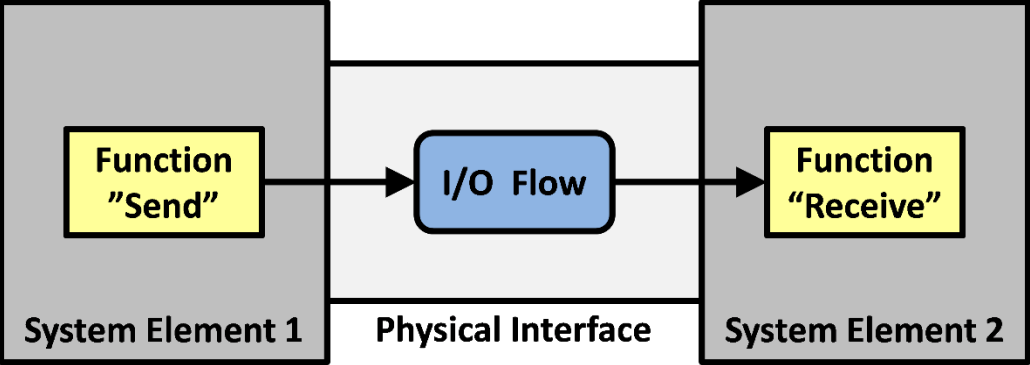
Functions

Physical allocation

Source: INCOSE SE Handbook v4

WHO – THE ROLE OF THE SYSTEM ARCHITECT

- Determining the overall architecture, style(s) to be employed, and implementation approach.
- Ensure architecture consistency

Credit: US Navy

Ensure the runaway is still there …

Architecture consistent decision

Pragmatic, inconsistent decision

(t)
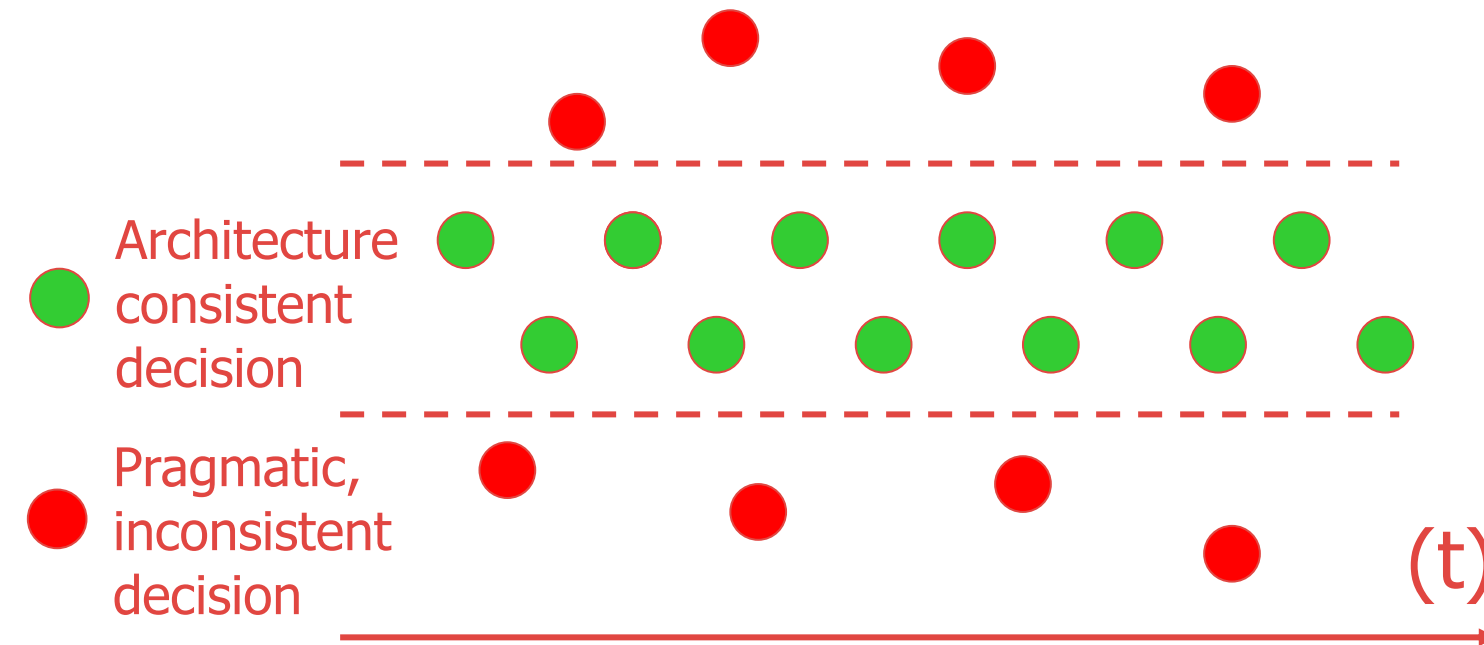
Harold "Bud" Lawson
15288:2002 Architect

WHERE TO FIND MORE INFO
(SOME SELECTED RESOURCES – THERE IS MUCH MORE)

- INCOSE SE Handbook, version 4, 2015
- www.SEBOKWIKI.org

Standards

- ISO/IEC/IEEE 15288:2015: Systems and Software Engineering - Systems lifecycle processes'. Standard, ISO/IEC/IEEE, 2015.
- ISO/IEC/IEEE 42010: 2011: Systems and Software Engineering - Architecture description'. Standard, ISO/IEC/IEEE, First edition, 2011.
- ISO/IEC/IEEE 42020: Enterprise, systems and software - Architecture processes'. Standard, ISO/IEC/IEEE, 2019.
- ISO/IEC/IEEE 42030: Systems and Software Engineering - Architecture evaluation'. Standard, ISO/ IEC/IEEE, 2019.
- OMG, Unified Architecture Framework Profile (UAFP), Available online at www.omg.org

Guides

- Rabbets, T, et al, Introduction to System Architecting, INCOSE UK, 2019
- Wilkinson, M and Rabbets, T, 'The Absolute Beginner´s Guide to Architecture and Architecting, INCOSE UK, 2021
- INCOSE Systems of Systems Primer, INCOSE-TP-2018-003-01.0, 2018
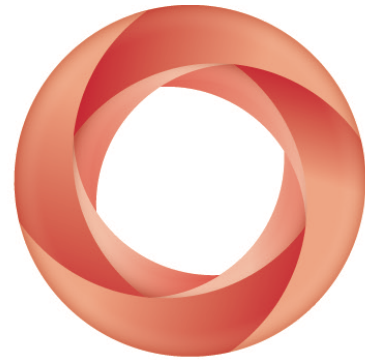
Papers

- Martin, James N, several papers on architecting and architecture frameworks, INCOSE Proceedings
- Martin, James N, Webinar on the Enterprise Architecture Guide for the Unified Architecture Framework (UAF), https://youtu.be/JrV_5XIzGvA
- Maier, Mark , Architecting principles for systems-of-systems, Systems Engineering Journal Vol 1 No 4, 1998: 267–284

Books

- Maier, M. and Rechtin, E. , The Art of Systems Architecting, CRC Press, Third edition, 2009.
- Sillitto, Hillary, Architecting Systems - Concepts, Principles and Practice, College Publications, 2014.
- Steven D. Eppinger and Tyson R. Browning , Design Structure Matrix Methods and Applications, 2012