Electrical Engineering and Computer Science Dept
College of Engineering

SYS530 - SYSTEM REQUIREMENTS ANALYSIS AND MODELING

Prof. Dr. Christopher Shneider Cerqueira

2025

Self Presentation

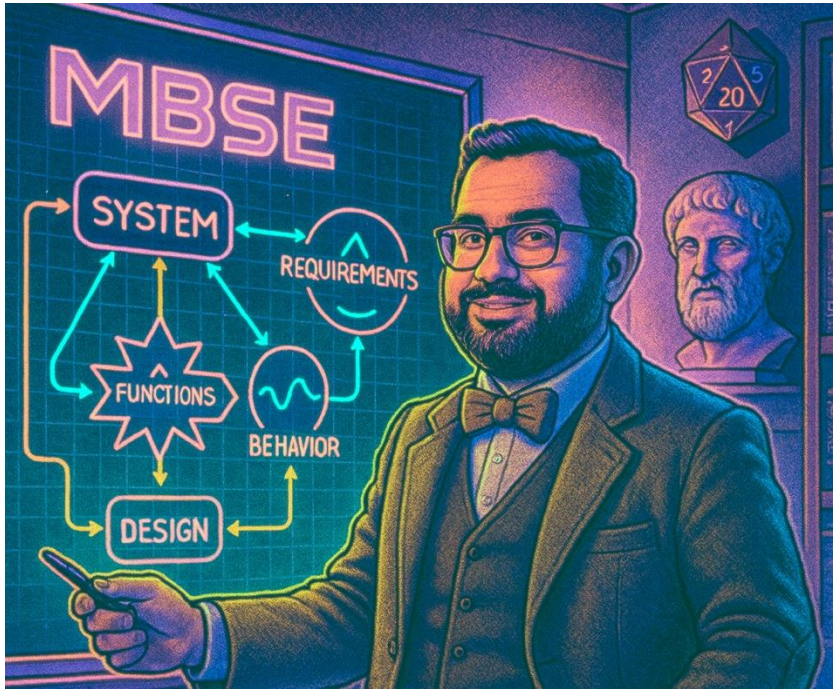




~~Prof. Dr.~~ **Christopher** S. Cerqueira

Prof. Dr. Christopher Shneider Cerqueira

- **Quick Educational Background Presentation**
  - Industrial Informatics Professional Technical School (ETEP – 1998-2003)
  - Computer Engineer – AR Researcher (UNIFEI – 2005-2011)
  - Space Engineering and Technology Master (INPE – 2012-2014)
  - Space Engineering and Technology PhD (INPE – 2014-2018)
  - Systems Engineering / Aeronautics & Aerospace Engineering Professor (ITA – 2018-2025)
  - Systems Engineering (ERAU – 2025-now)

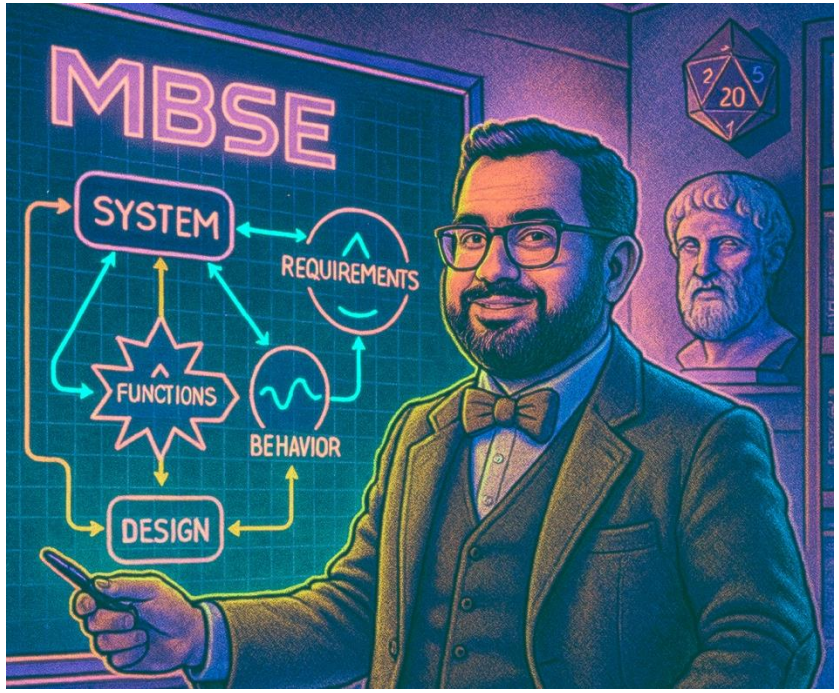


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www.cscerqueira.com.br

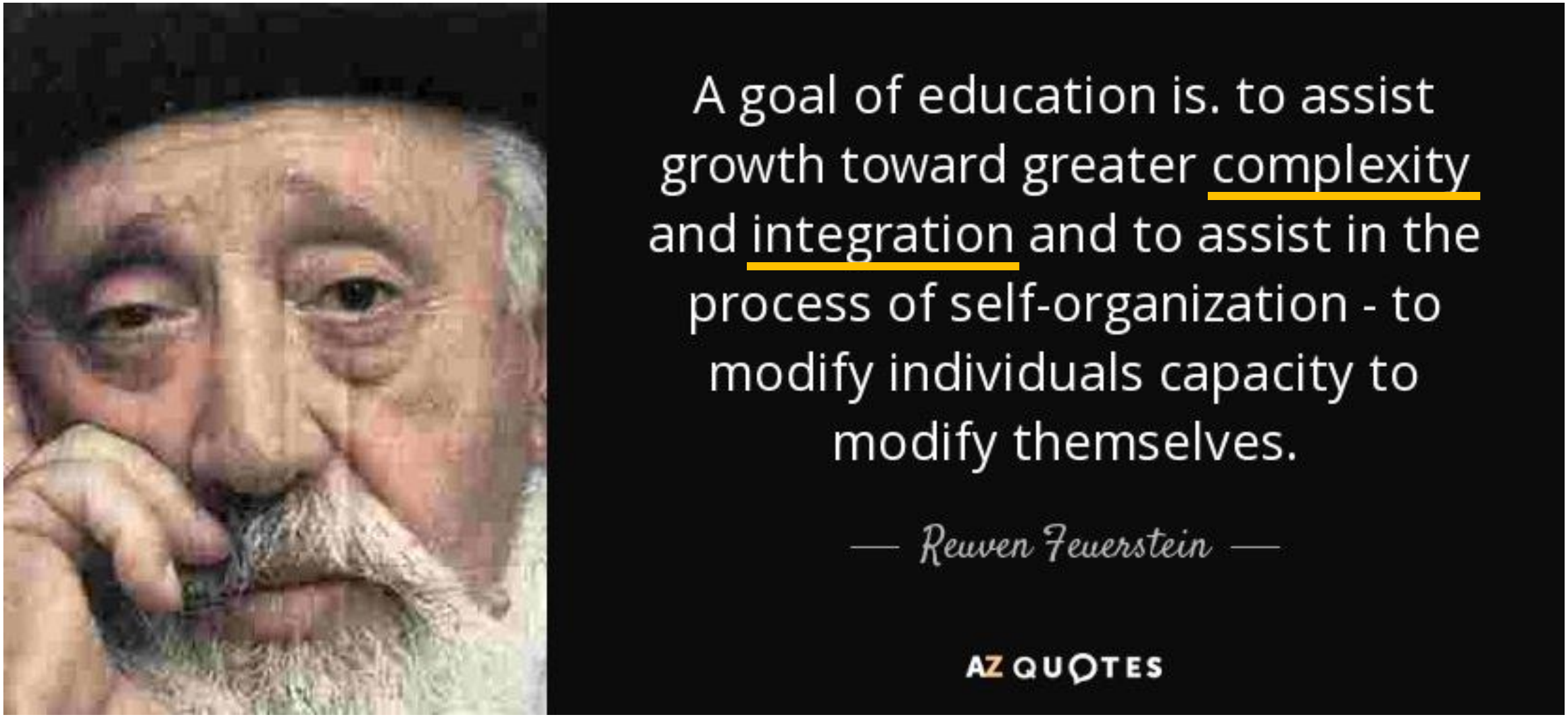
Let's be friends in Pokémon GO! My Trainer Code is 512244814898!

Prof. Dr. Christopher Shneider Cerqueira

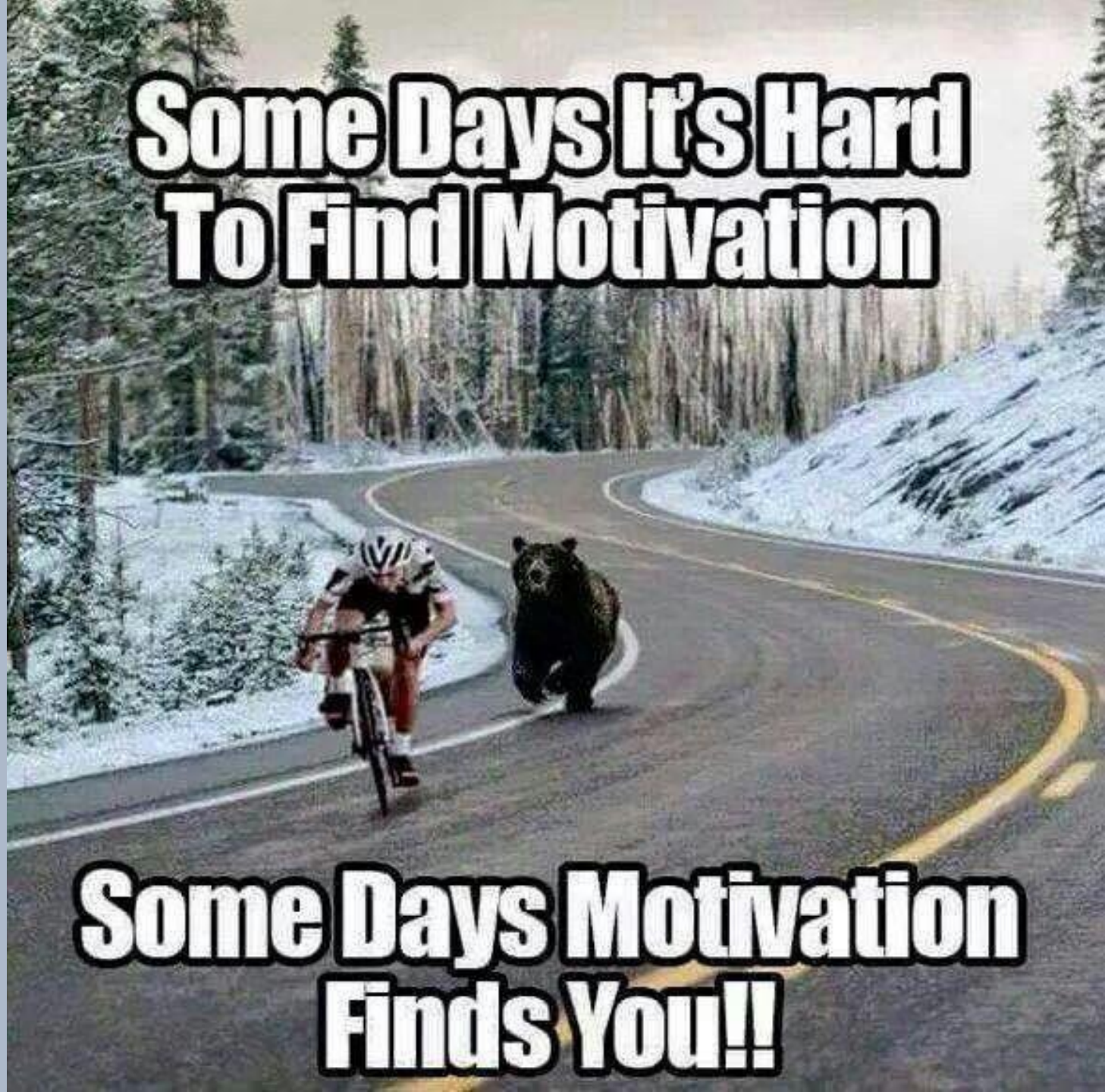
- **Quick Industry Background Presentation**
  - Product Line experience developing embedded systems (then called microcontroller programming).
  - FPGA development for missile on-board computers.
  - Augmented Reality projects supporting digital transformation in museums.
  - Worked in Satellite Integration Rooms.
  - Experience in Concurrent Design Facilities for space mission design.
  - Reviewer/manager of life-cycle, architectures, and requirements for projects of the Brazilian Space Agency and the Brazilian Air Force.
  - Systems Engineering of the UTM effort at Brazil.
  - And now—I'm here! 🙂

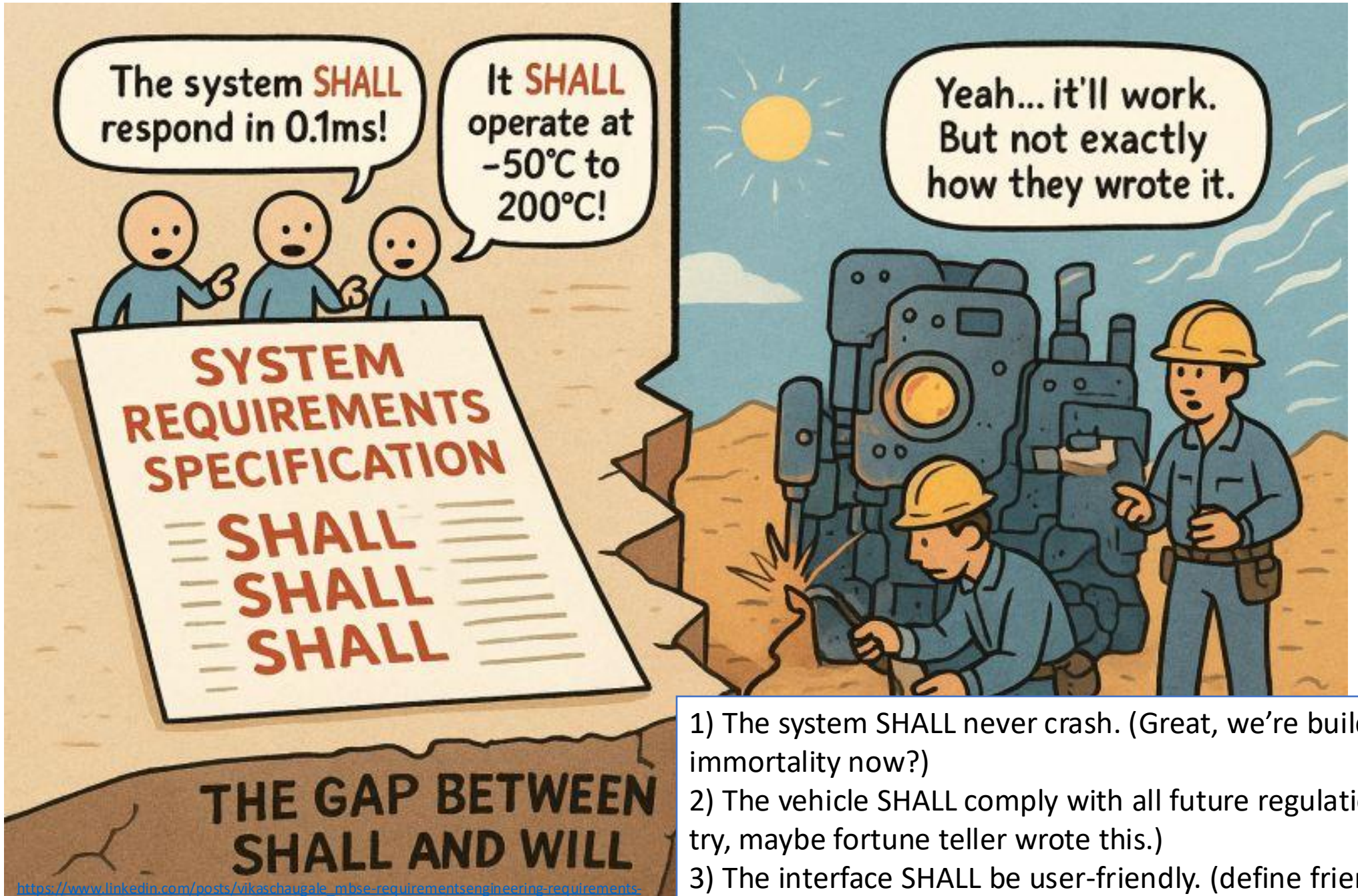


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A goal of education is. to assist growth toward greater complexity and integration and to assist in the process of self-organization - to modify individuals capacity to modify themselves.
— Reuven Feuerstein —
AZ QUOTES

MOTIVATION

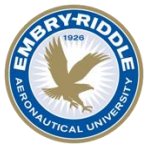

Some Days It's Hard
To Find Motivation
Some Days Motivation
Finds You!!



https://www.linkedin.com/posts/vikaschaugale_mbse-requirementsengineering-requirements-activity-7365971263267217408-U4Wq?utm_source=share&utm_medium=member_desktop&rcm=ACoAAALscwcB3JrZAFuPhjdKigpOvU0DvIzws3s

1) The system SHALL never crash. (Great, we're building immortality now?)
2) The vehicle SHALL comply with all future regulations. (Nice try, maybe fortune teller wrote this.)
3) The interface SHALL be user-friendly. (define friendly. handshakes? compliments?)

What is a Requirement?



What is a Specification?

What is a Requirement Specification?

How do we **guarantee** that we made the **system right**?

How do we **guarantee** that we made the **right system**?

Academic Contract

https://erau.simplesyllabus.com/doc/e4iycyfoq/Daytona%2FPrescott-2025-Fall-DB-SYS-530-01DB-System-Requirements-Analysis-and-Modeling?mode=view

SYS 530 System Requirements Analysis and Modeling 3 Credits (3,0)

- This course is concerned with the development, definition, and management of requirements for system or product.
- Topics include the system requirements process, requirements elicitation techniques, alternative requirements analysis techniques, requirements specification, requirements verification and validation, requirements management, and requirements standards and tools.
- Issues such as stakeholder identification, risk analysis, trade off analysis as it relates to the requirements will be covered.

Course Goals

- **SYS530-01DB-CG-01** - Students will learn how to analyze and
- **SYS530-01DB-CG-02** - validate customer needs,
- **SYS530-01DB-CG-03** - expectations, and
- **SYS530-01DB-CG-04** - system concepts in the development of system requirements.
- **SYS530-01DB-CG-05** - They will explore techniques for defining and
- **SYS530-01DB-CG-06** - techniques for modeling system requirements
- **RATIONALE:** that align with both customer and developer goals throughout the system realization process

Student Learning Outcomes

- Describe the essential elements of system requirements engineering.
- Distinguish between various requirements specification techniques.
- Analyze requirements specifications for validation and verification purposes.
- Formulate requirements and specifications for large-scale software and systems.
- Identify tools and techniques for systems requirements management.

References

[01] INCOSE's Systems Engineering Handbook - https://erau.primo.exlibrisgroup.com/permalink/01ERAU_INST/15kv1ds/alma995863348305946

[02] INCOSE's Needs and Requirements Manual - https://erau.primo.exlibrisgroup.com/permalink/01ERAU_INST/15kv1ds/alma995949588205946

[03] INCOSE's Guide for Write Requirements

[04] INCOSE's Guide for Verification and Validation

[05] Requirement Engineering - Jeremy Dick / Elizabeth Hull / Ken Jackson - https://erau.primo.exlibrisgroup.com/permalink/01ERAU_INST/osfi0l/cdi_biblioboard_primary_oai_biblioboard_com_fd7da38c_b08e_4a84_b144_8293c62a4cef

[06] A Handbook for Systems Engineering, Requirements Engineering, and Software Engineering Using Planguage - Tom Gilb - https://erau.primo.exlibrisgroup.com/permalink/01ERAU_INST/15kv1ds/alma995586414505946

[07] ISO/IEC/IEEE 29148:2011(E) : ISO/IEC/IEEE International Standard - Systems and software engineering -- Life cycle processes --Requirements engineering - https://erau.primo.exlibrisgroup.com/permalink/01ERAU_INST/15kv1ds/alma995545081005946

[08] Requirements Engineering: Laying a Firm Foundation - James A. Crowder / Curtis W. Hoff - https://erau.primo.exlibrisgroup.com/permalink/01ERAU_INST/15kv1ds/alma995850007505946

[9] Exploring Requirements - Quality Before design - Donald C. Gause / Gerald M. Weinberg - https://erau.primo.exlibrisgroup.com/permalink/01ERAU_INST/15kv1ds/alma99372423405946

[10] Mastering the Requirement Process - Suzanne Robertson / James Robertson - https://erau.primo.exlibrisgroup.com/permalink/01ERAU_INST/15kv1ds/alma995930159005946

W	Dates	Topic	Ref	Activity
35	26-Aug	Course Introduction Systems Engineering Review Requirement Engineering (Generic Process)	[1][6] [7][9]	Groups & Names
36	2-Sep	Lego exercise 01 - First assessment	[2] [10]	Exercise Report
37	9-Sep	Definition and Structure of Requirements Functional and non-functional Requirements	[8][6] [10]	Exercise List
38	16-Sep	Elicitation Techniques (Interview / Rich Picture / use Cases)		Group Project Delivery
39	23-Sep	Rules for need and requirement statements	[2][3]	Exercise List
40	30-Sep	Attributes of need and requirement statements Boilerplates/patterns	[2]	Exercise List
41	7-Oct	[Carrer Explo]		* Reading activity
42 *	14-Oct	Midterm Session		Self-paced concept questions
		[Fall break]		

W	Dates	Topic	Ref	Activity
43	21-Oct	MBSE Trends	**	Group Project Delivery
44	28-Oct	Traceability - Organization	[5][	Group Project Delivery
45	4-Nov	Metadata: Rationale + Verification and Validation (Success Criteria)	[2][4]	Group Project Delivery
46	11-Nov	[Veterans Day]		* reading activity
47	18-Nov	Lego Exercise 02	[2] [10]	Exercise Report
48	25-Nov	System Requirement Review Presentation (G1-G4)		
		[Thanksgiving]		
48	2-Dec	System Requirement Review Presentation (G5-G8)		
49	9-Dec	Finals		Self-paced concept questions and a small case

- Level 4 – Self-Assessment (10%)

- Level 3 – Group Case (Report-Presentation) (40%)
  - Group reports. (50% of)
  - Presentation (50% of)

- Level 2 – Final Individual Exam (15%)
  - Final quiz (10 questions max + case)

- Level 1 – Mid Individual Exam (15%)
  - Mid quiz (10 questions max + case)

- Level 0 – Homework Quizzes/Lists (20%)
  - quizzes w/ max 10 questions each.



Final considerations

- This course is being **"organized to ERAU".**
- **Problems** are expected.
  - *We are going to work hard to solve them*.
- *Expecting **feedbacks and lessons learned through the semester**.*
- ***We need*** to be **patience** in this endeavor.
  - Hope you have fun **learning** through the course.



A little background before we start….

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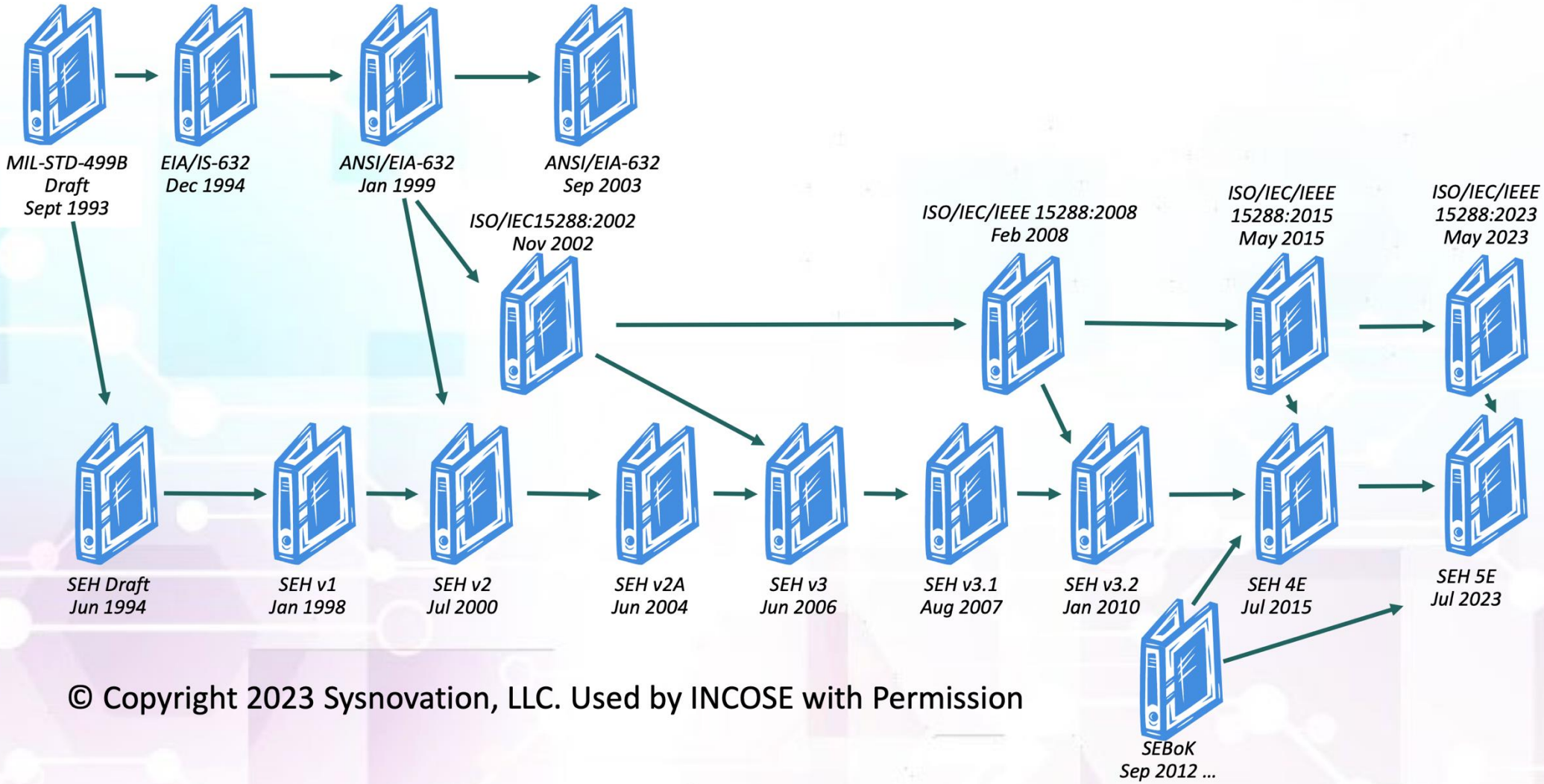
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INTERNATIONAL COUNCIL ON SYSTEMS ENGINEERING

INCOSE Systems Engineering Handbook (SEH) History



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Three Main SEH Inputs

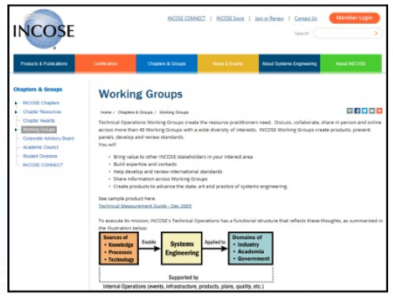
ISO/IEC/IEEE 15288 standard

- Developed by the consensus of SE experts from government, industry, and academia
- Defines a set of processes and associated terminology



INCOSE Working Groups

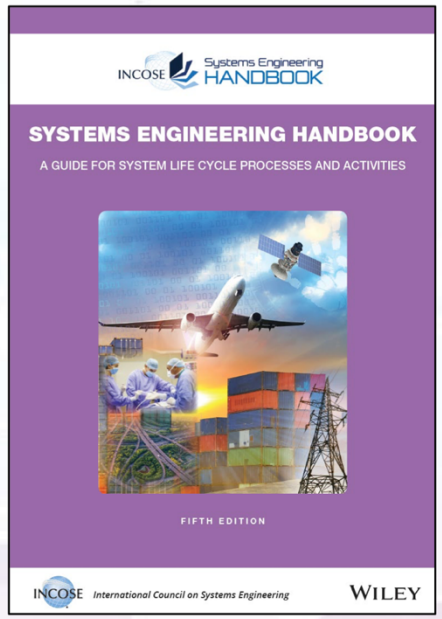
- Subject Matter Experts from the INCOSE technical community serve as section authors
- Handbook includes summaries and pointers to INCOSE Working Group products



SE Body of Knowledge (SEBoK)

- Reflects the state-of-the-knowledge of Systems Engineering
- Provides a widely accepted, community-based, and regularly updated wiki-based baseline of SE knowledge

SEBoK
GUIDE TO THE SYSTEMS ENGINEERING BODY OF KNOWLEDGE



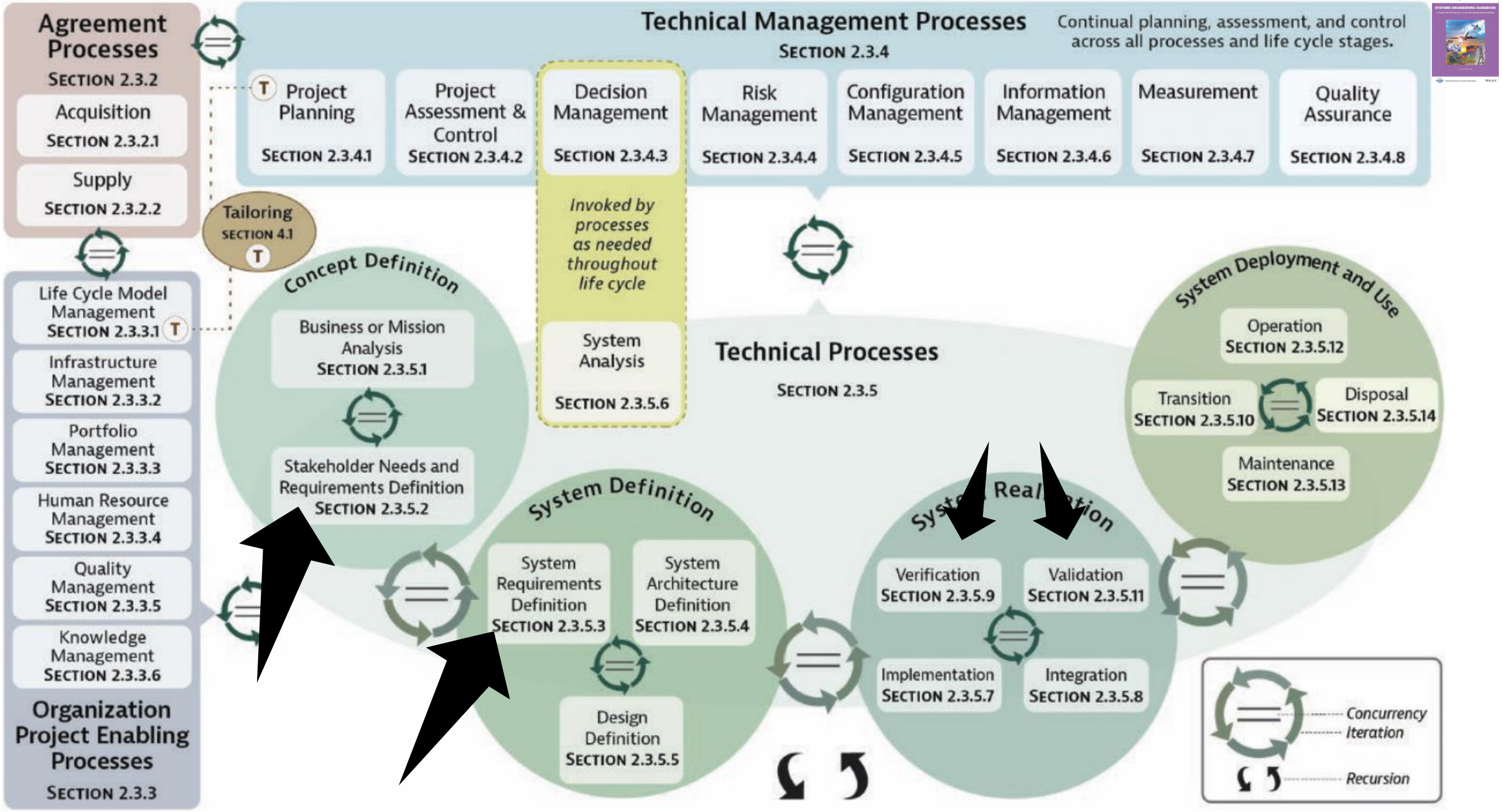


FIGURE 2.10 System life cycle processes per ISO/IEC/IEEE 15288. INCOSE SEH original figure created by Roedler and Walden. Usage per the INCOSE Notices page. All other rights reserved.

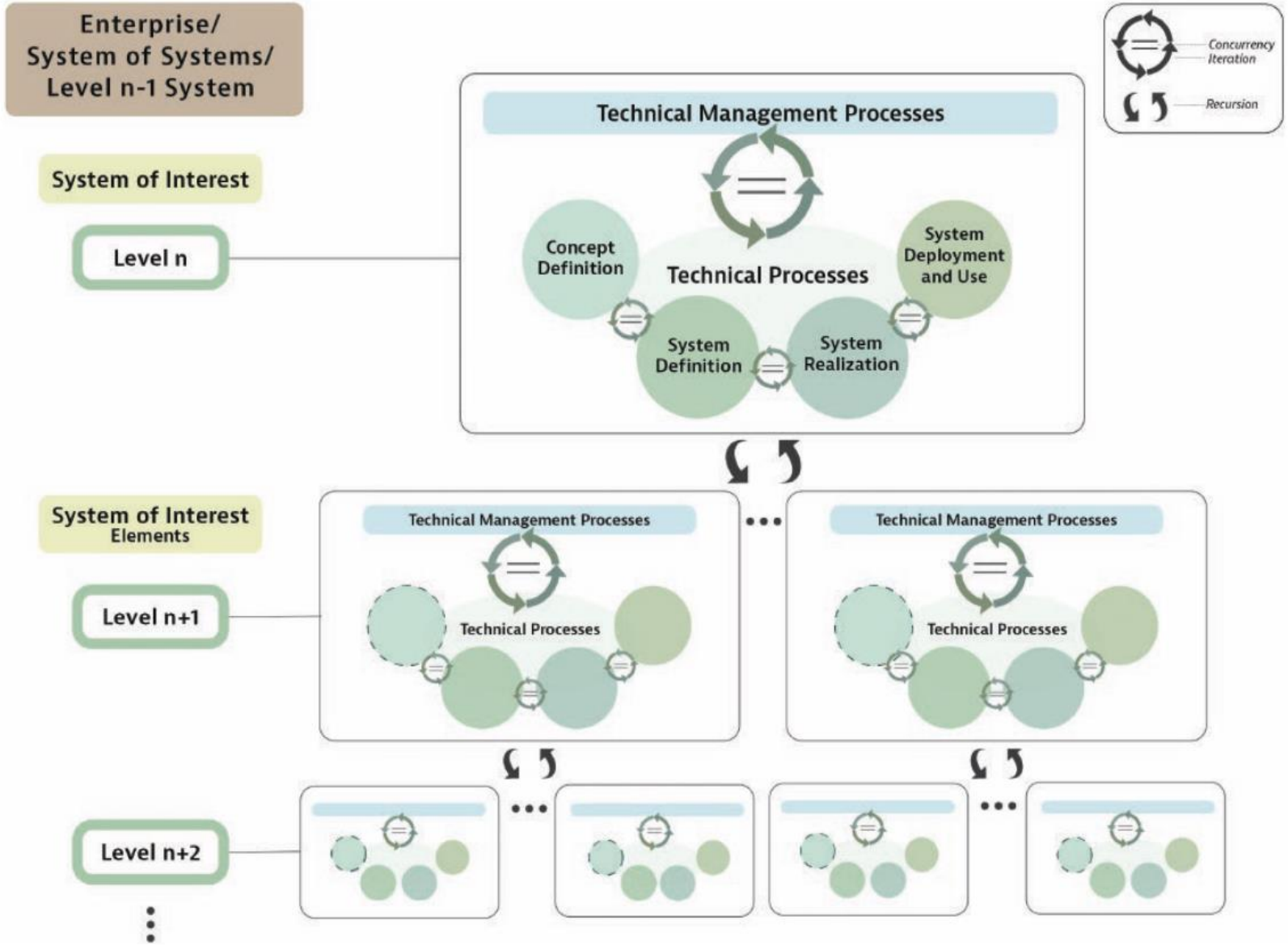
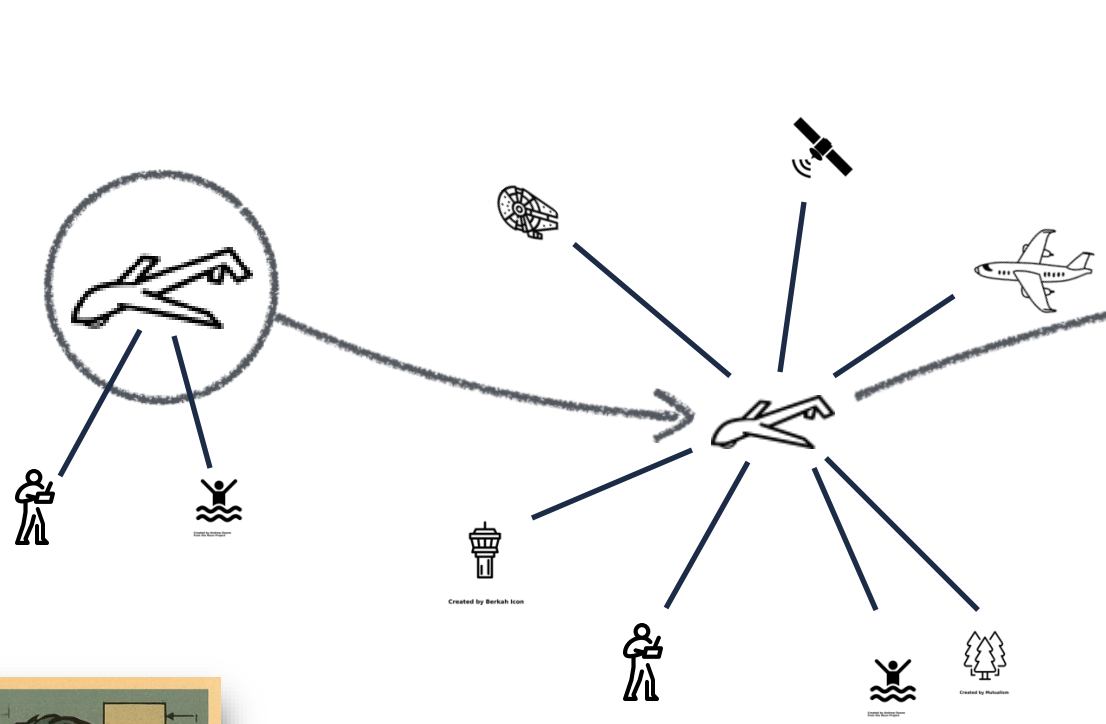
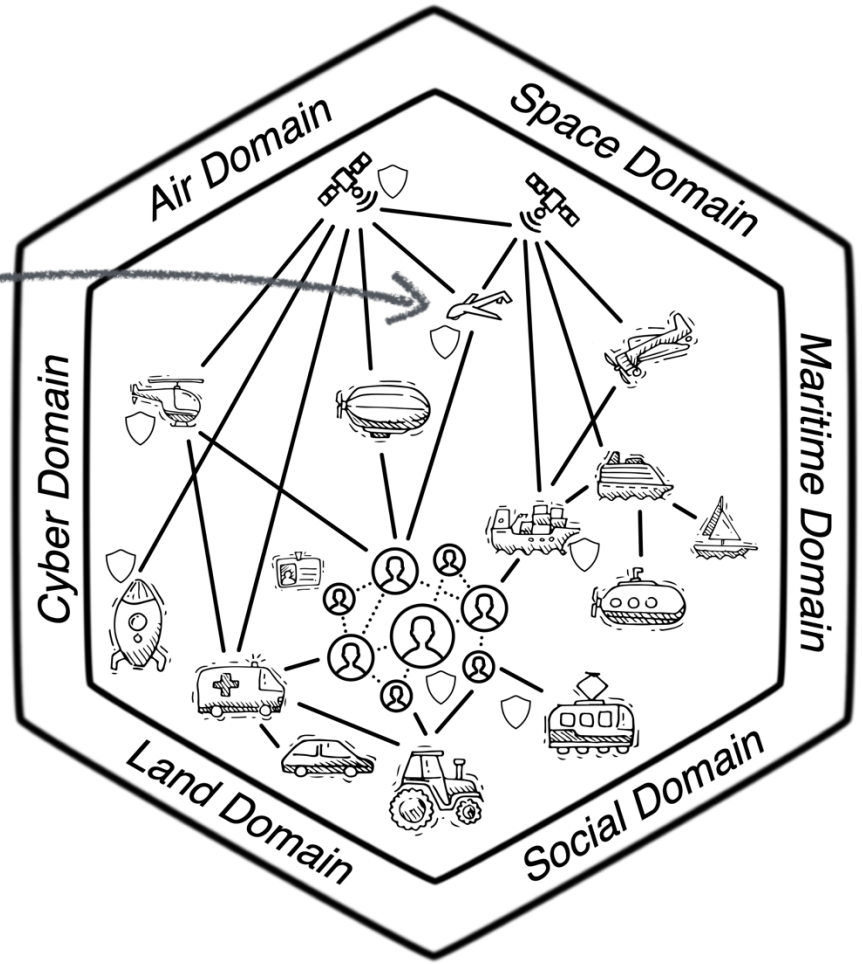


FIGURE 2.12 Concurrency, iteration, and recursion. INCOSE SEH original figure created by Roedler and Walden. Usage per the INCOSE Notices page. All other rights reserved.

Systems Engineering





NATO - MultiDomain Framework **+ Social**

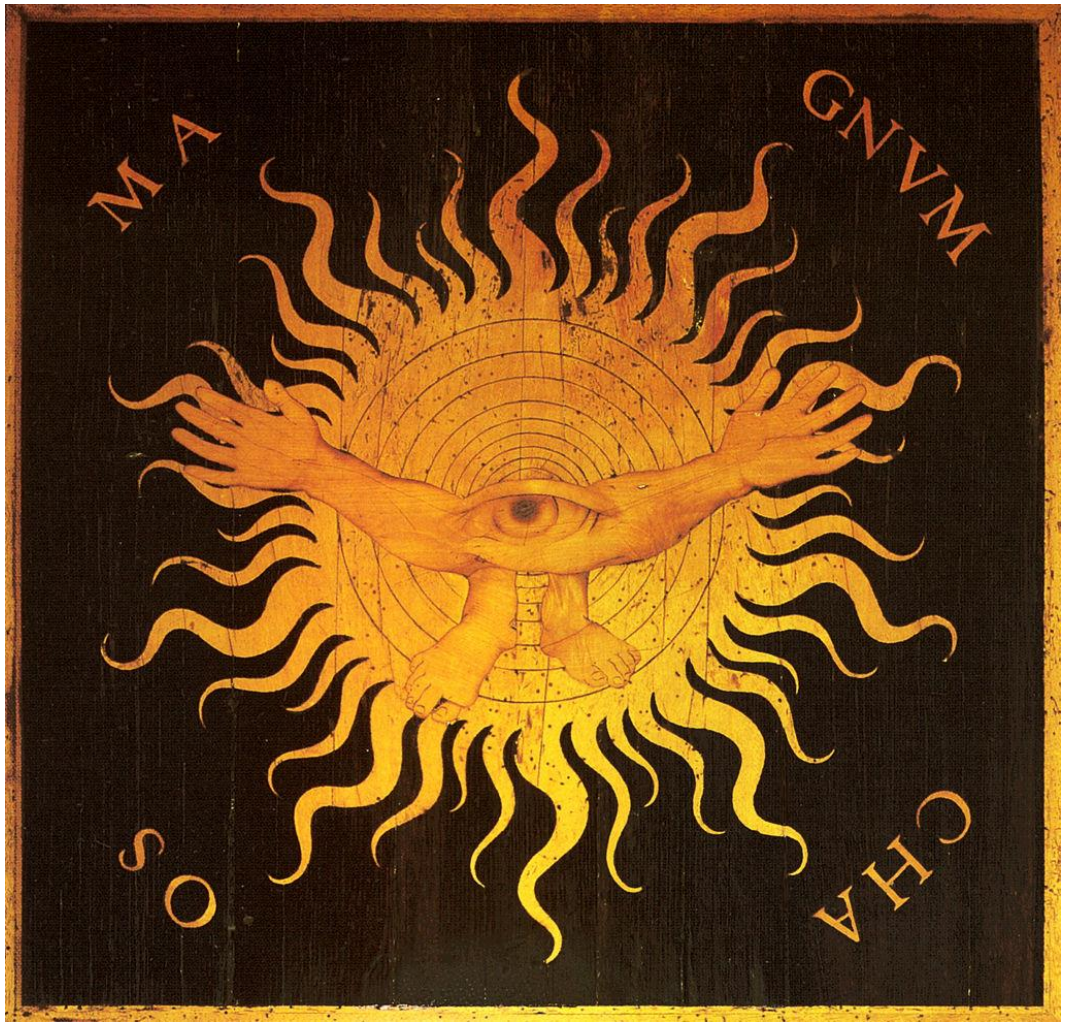


https://www.act.nato.int/article/mdo-in-nato-explained/

https://sebokwiki.org/wiki/System_Resilience

Super Fast Systems Engineering Review

At the beginning there was only chaos

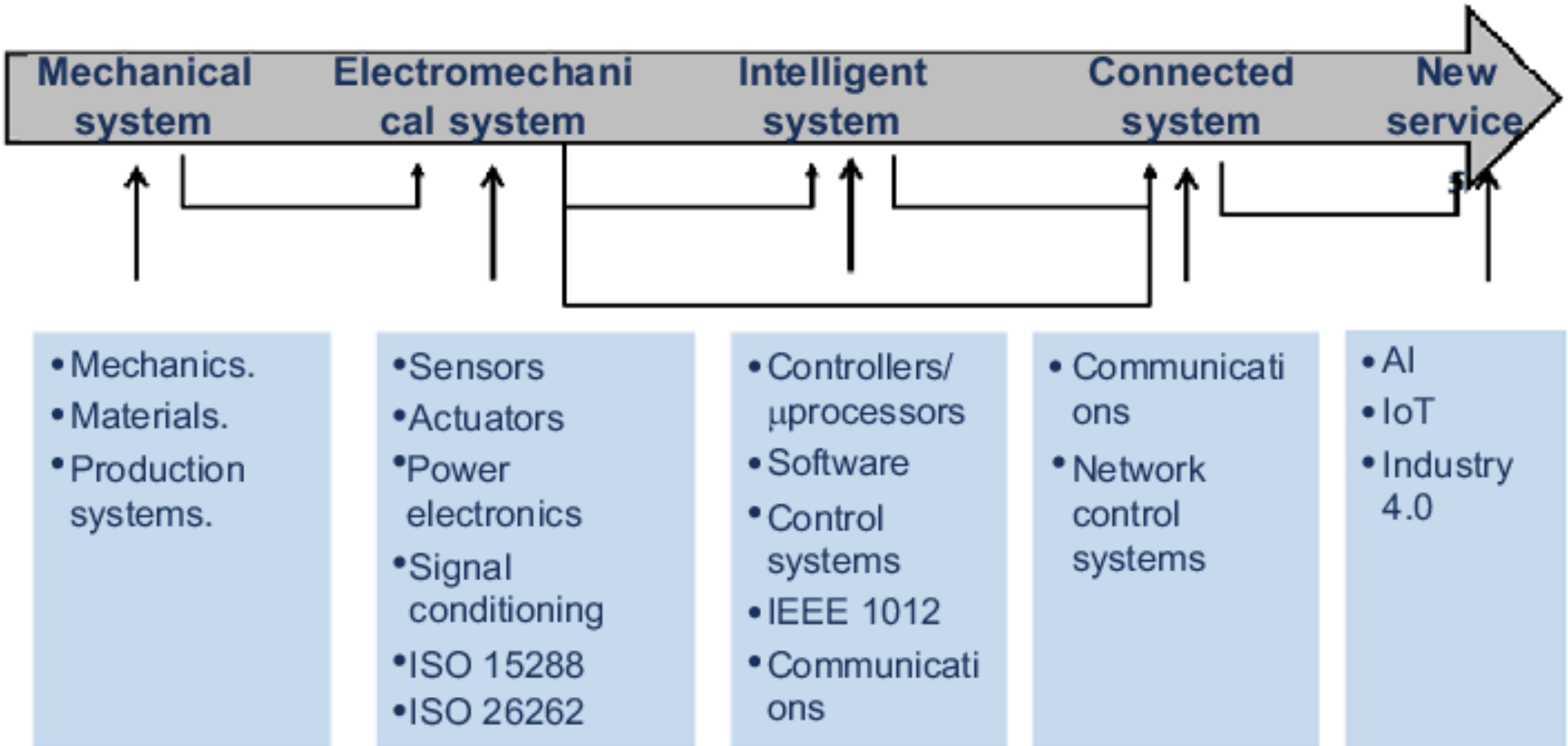


- **At the beginning there was only Chaos, Night, dark Erebus, and deep Tartarus. Earth, the air and heaven had no existence.** [695] Firstly, blackwinged Night laid a germless egg in the bosom of the infinite deeps of Erebus, and from this, after the revolution of long ages, sprang the graceful Eros with his glittering golden wings, swift as the whirlwinds of the tempest. He mated in deep Tartarus with dark Chaos, winged like himself, and thus hatched forth our race, which was the first to see the light. [700] That of the Immortals did not exist until Eros had brought together all the ingredients of the world, and from their marriage Heaven, Ocean, Earth and the imperishable race of blessed gods sprang into being. Thus our origin is very much older than that of the dwellers in Olympus. We are the offspring of Eros; there are a thousand proofs to show it. We have wings and we lend assistance to lovers. [705] How many handsome youths, who had sworn to remain insensible, have opened their thighs because of our power and have yielded themselves to their lovers when almost at the end of their youth, being led away by the gift of a quail, a waterfowl, a goose, or a cock.

Chaos (cosmogony) - Wikipedia

Aristophanes, Birds, line 685 (tufts.edu)

The growth of complexity in systems



https://doi.org/10.4271/12-03-02-0011



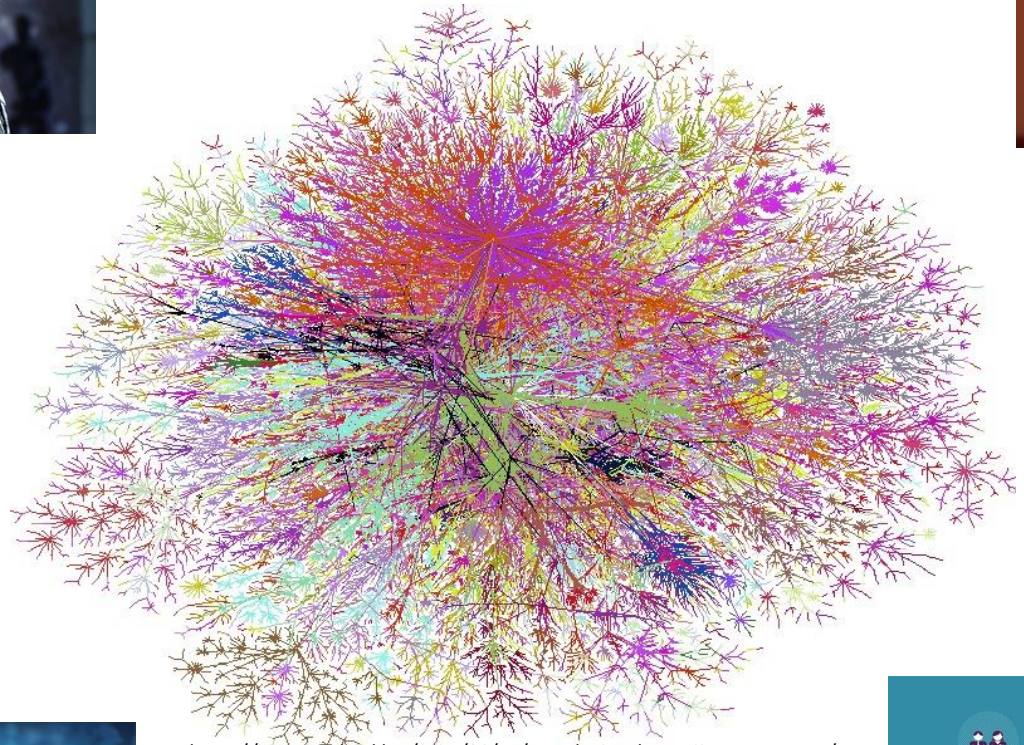


Ending scene from 1971 movie THX 1138



https://www.youtube.com/watch?v=atMdf0rhbpI





https://ioannouolga.blog/2017/09/14/complexity-theory-ii-m-woermann/









What is Systems Engineering?

Systems Engineering is **a transdisciplinary approach and means**, based on systems principles and concepts, to enable the successful realization, use and retiral of engineered systems.

It focuses on

- establishing stakeholders' **purpose and success criteria**, and defining actual or anticipated customer needs and required functionality early in the development cycle,
- establishing an **appropriate lifecycle model** and process approach considering the levels of complexity, uncertainty and change
- documenting and **modelling requirements** and **solution architecture** for each phase of the endeavour
- proceeding with **design synthesis and system validation**
- while considering the **complete problem** and **all necessary enabling systems and services**.

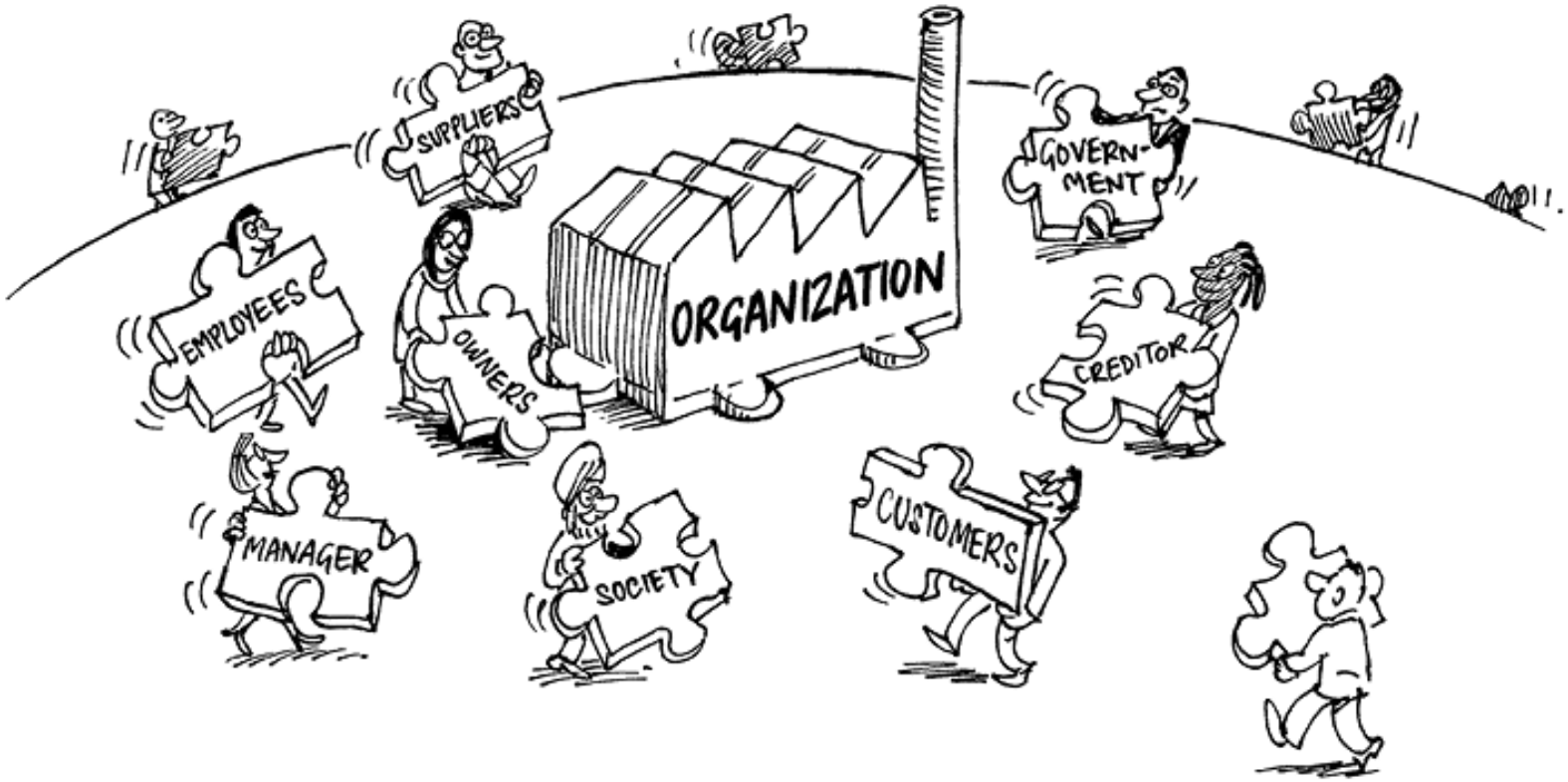
Systems Engineering provides facilitation, guidance and leadership to integrate all the disciplines and specialty groups into a team effort forming an appropriately structured development process that proceeds from concept to production to operation, evolution and eventual disposal.

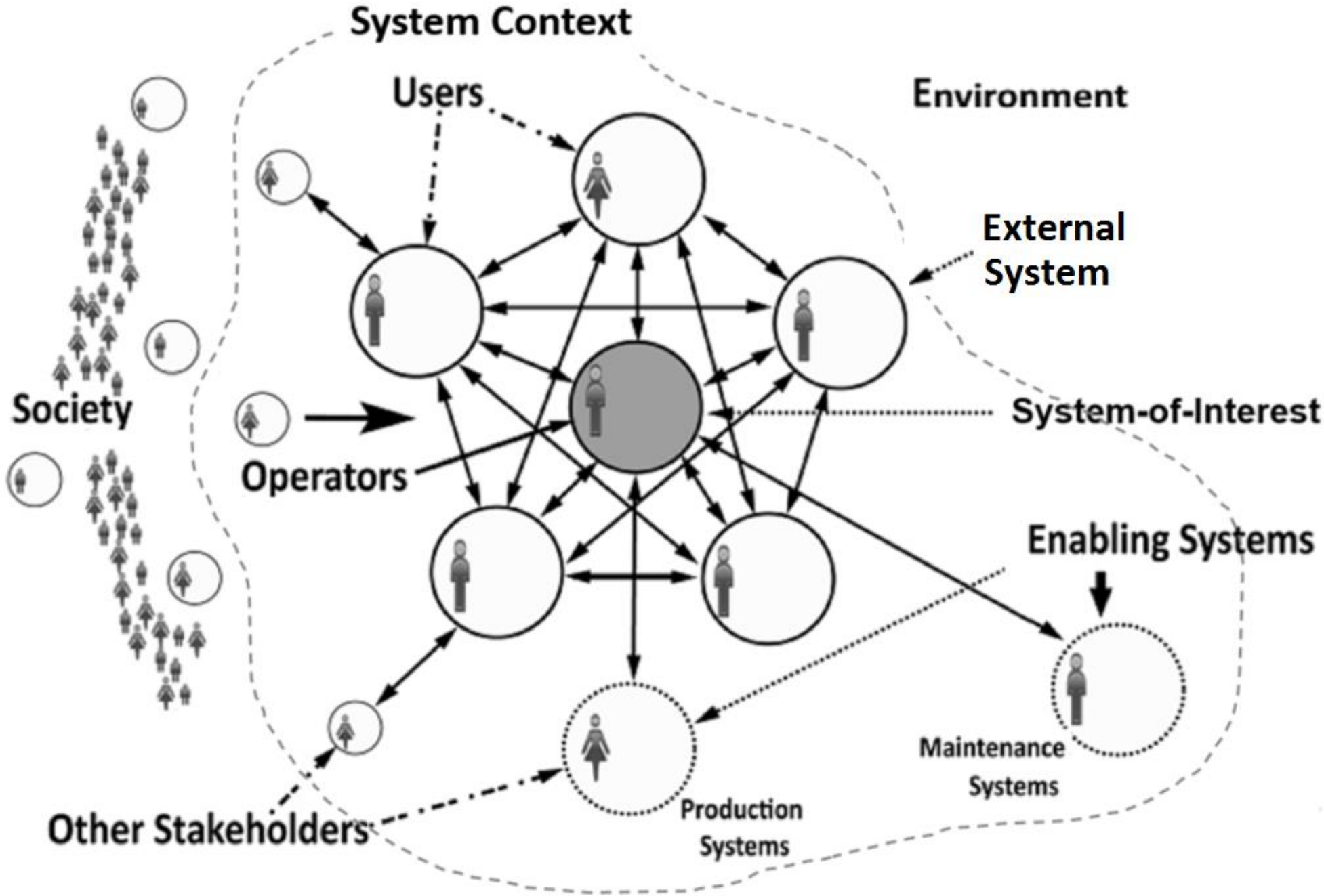
Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality solution that meets the needs of users and other stakeholders and is fit for the intended purpose in real-world operation, and avoids or minimizes adverse unintended consequences.

Stakeholders

Stakeholders

- A stakeholder is any individual, group or organization that can affect, be affected by a project.

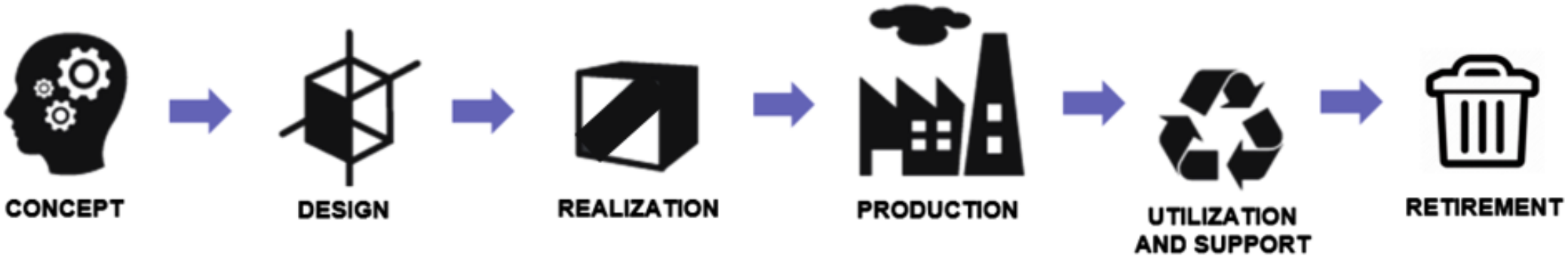



System Context
Users
Environment
External System
Society
System-of-Interest
Operators
Enabling Systems
Maintenance Systems
Production Systems
Other Stakeholders

Life cycle

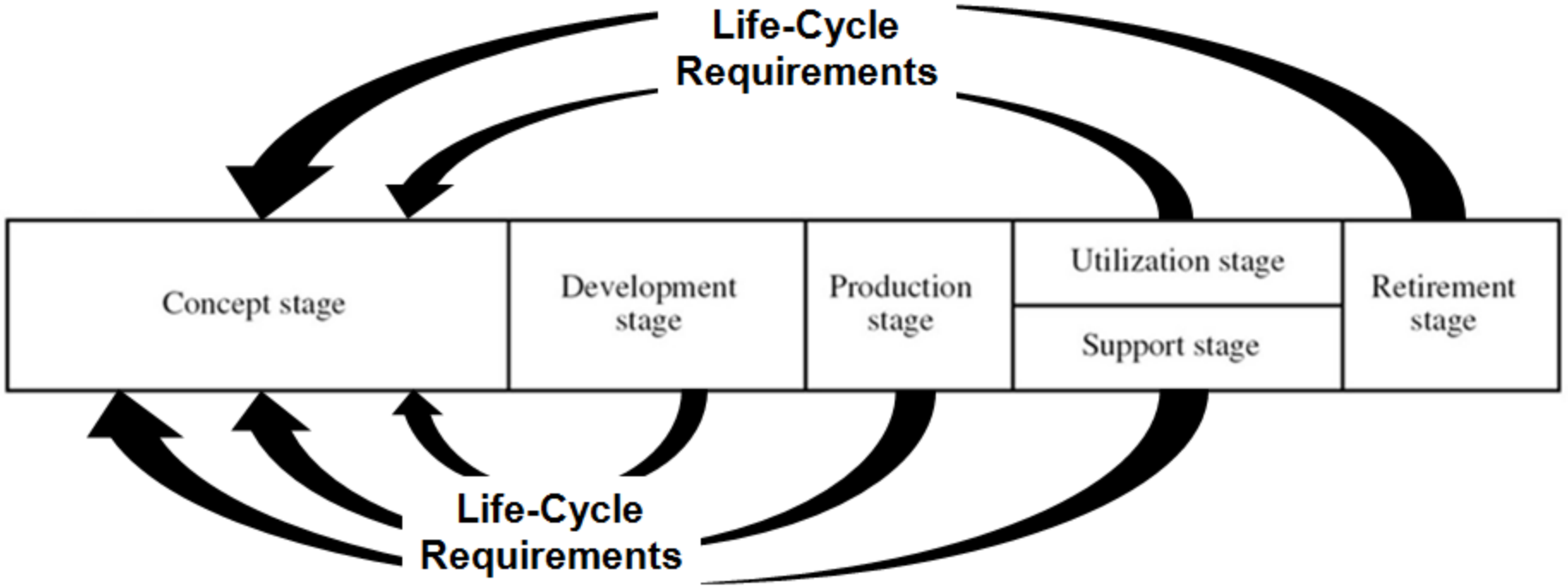
Life cycle

- Engineered Systems have a **life cycle.**
  - Life cycle is a series of **stages through which a system passes** during its lifetime
  - Life cycle considers the evolution of a system **from conception through retirement**



Life cycle requirements

- Life cycle requirements promote the **anticipated understanding** about future system attributes

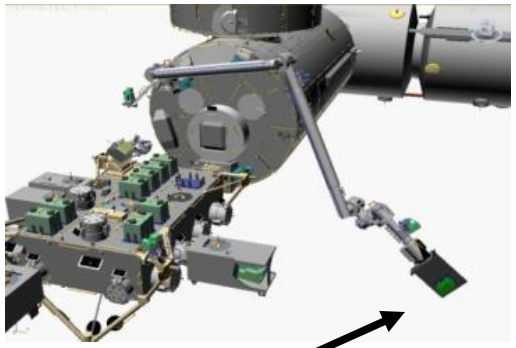


CONOPs

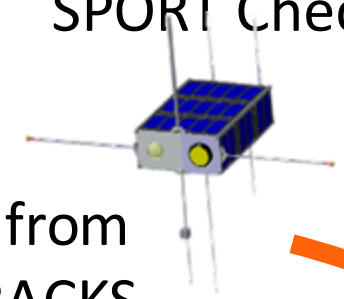
What is a CONOPS?

- Description of **how** the System will be operated to meet stakeholder expectations
- Explains your system's characteristics from an operational perspective and helps facilitate an understanding of the **system's purpose**
- Illustrates a day in the life of your system's **intended use**

CONOPS Example: SPORT

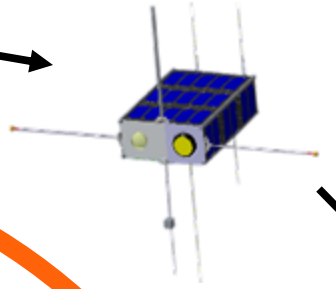


SPORT Checkout



SPORT Operations

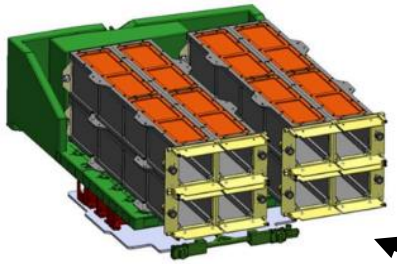
On-orbit Operations
(> 12 months)



Disposal
300 km
alt

Deploy from
NANORACKS
400 km alt

Installation



Launch



Soft
Package



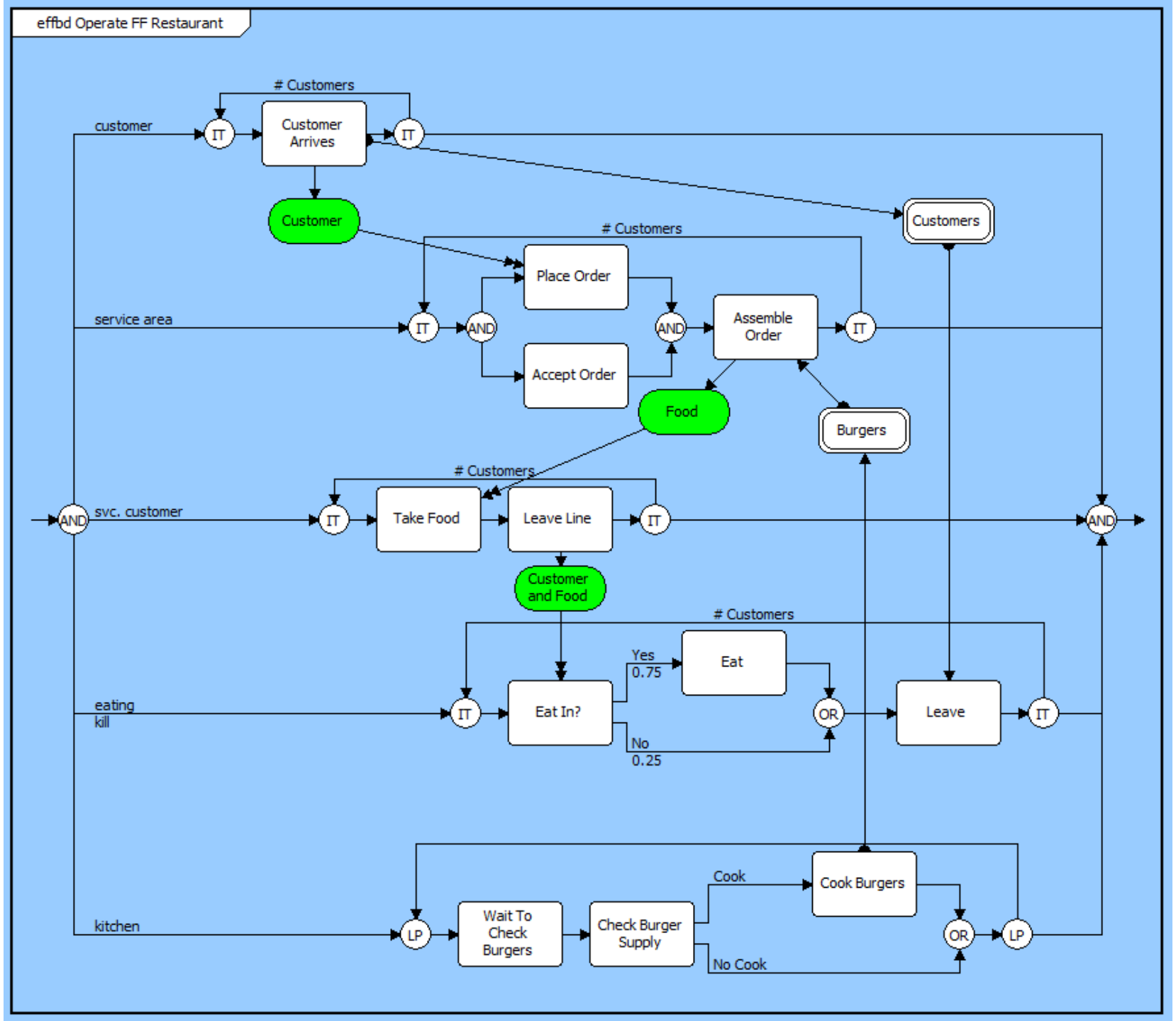
Images: Charlie Gray



Functions

Function (action/activity)

- A function is an **action, an operation or a service**, performed by the system or one of its components, or also by an actor interacting with the system.
- Performing a **function generally produces exchange items** expected by other functions, and to do this, it requires other items provided by other functions.
- Several **functions can be grouped** into a mother function (they are then called subfunctions, or daughter functions, of this function). Symmetrically, a function can be refined into several functions.
- By convention, a function is named with a **verb**.



[Enhanced Function Flow Block Diagram (EFFBD) (vitechcorp.com)]

Requirements

requirement [ri-**kwahy*uh*** r-m*uh* nt] SHOW IPA

SEE SYNONYMS FOR *requirement* ON THESAURUS.COM

noun

1. that which is required; a thing demanded or obligatory:
   One of the requirements of the job is accuracy.
2. an act or instance of requiring.
3. a need or necessity:
   to meet the requirements of daily life.

TO DO or NOT TO DO

- **Functional Requirements** describe what the system should do and **Non-functional Requirements** place constraints on how these functional requirements are implemented.



Verification

- The verification of a product shows **proof of compliance with requirements** – the product can meet each "must" claim as proven through the performance of a test, analysis, inspection or demonstration (or combination of these).
- **Verification is a process of confirming that a requirement or system is compliant**.
  - In other words, the system checker asks the question: **Does the system meet your requirements?**
  - The requirements checker asks the question: **Does the system really meet this specific requirement?**

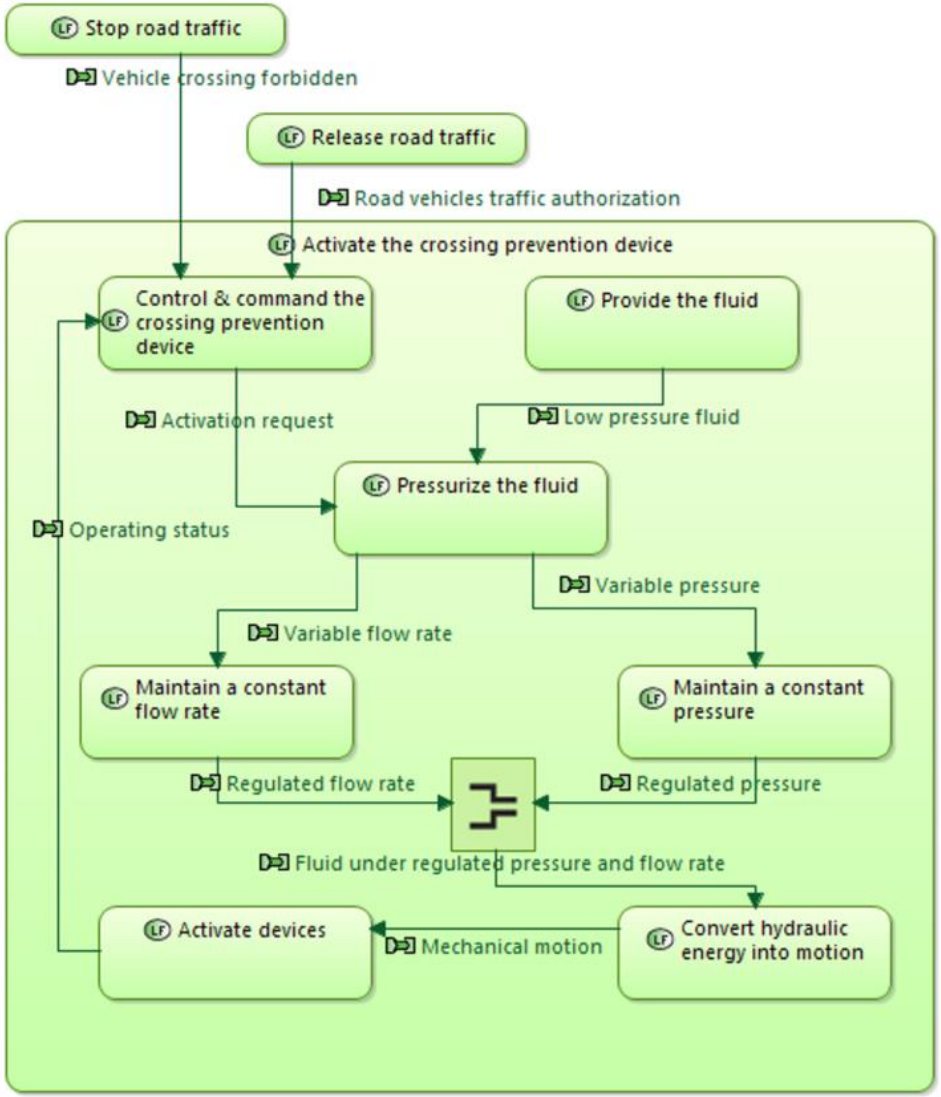
Validation

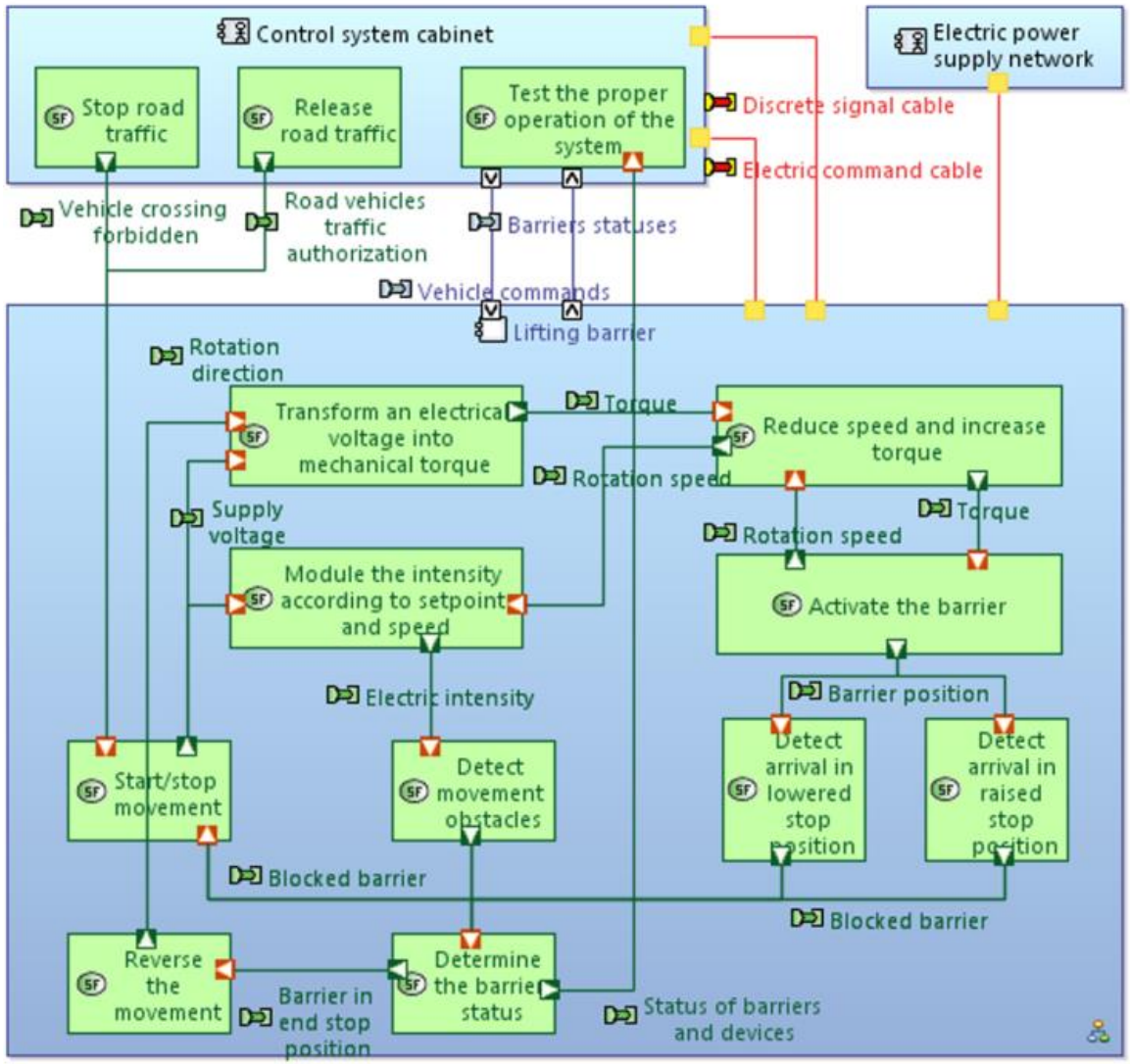
- VALIDATION of a product shows that the **product fulfills its intended purpose in the intended environment** – that it meets the expectations of the customer and other stakeholders, as demonstrated by the performance of a test, analysis, inspection, or demonstration.
- Validation is a process of confirming that a set of requirements, design, or system **meets the intent** of the developer or customer.

Architecture

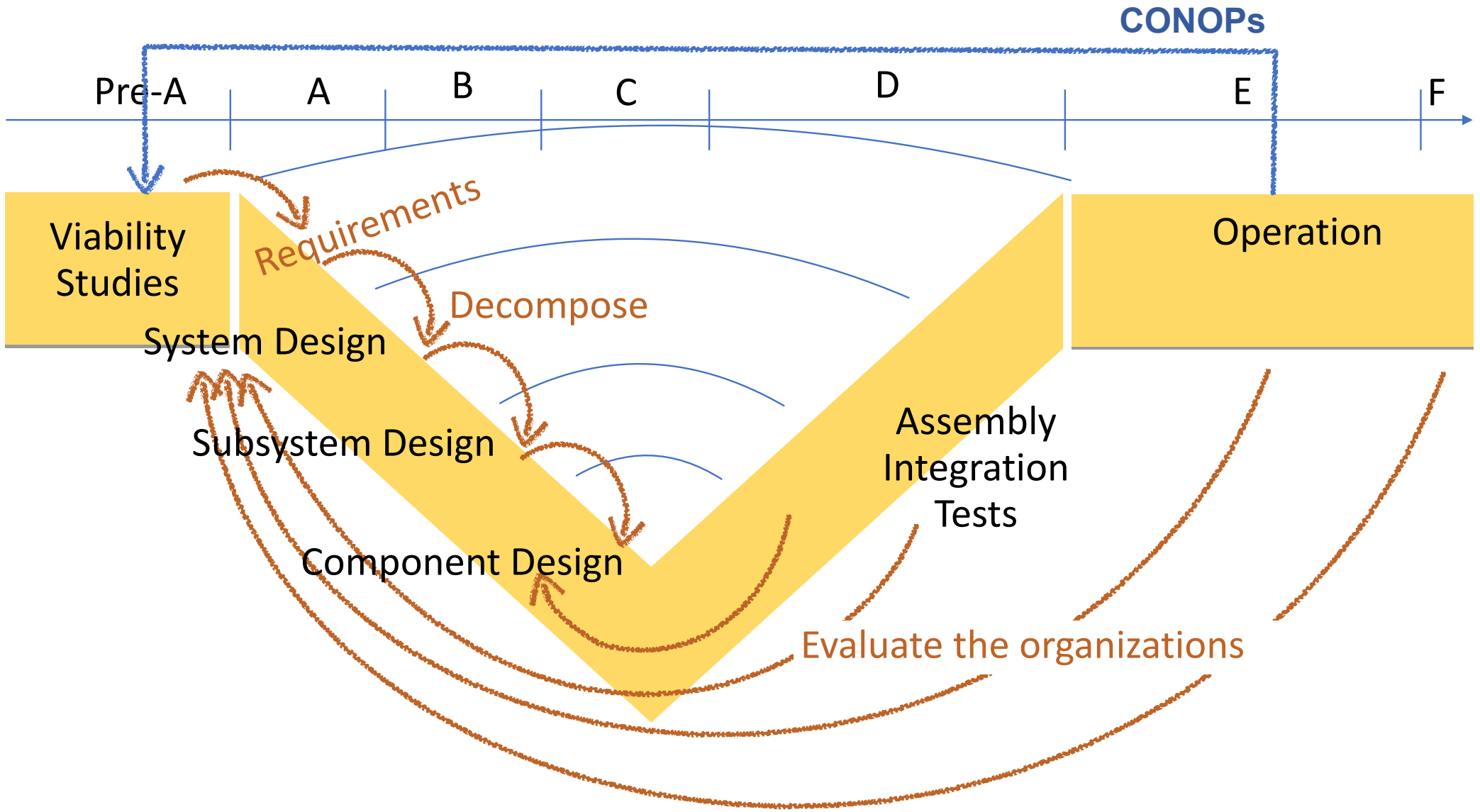
- System architecture is the **embodiment of *concept***, the **allocation of physical/informational *function* to the elements of *form***, and the **definition of *relationships* among the elements** and with the **surrounding *context***.

Examples


Stop road traffic
Vehicle crossing forbidden
Release road traffic
Road vehicles traffic authorization
Activate the crossing prevention device
Control & command the crossing prevention device
Provide the fluid
Activation request
Low pressure fluid
Pressurize the fluid
Operating status
Variable pressure
Variable flow rate
Maintain a constant flow rate
Maintain a constant pressure
Regulated flow rate
Regulated pressure
Fluid under regulated pressure and flow rate
Activate devices
Mechanical motion
Convert hydraulic energy into motion

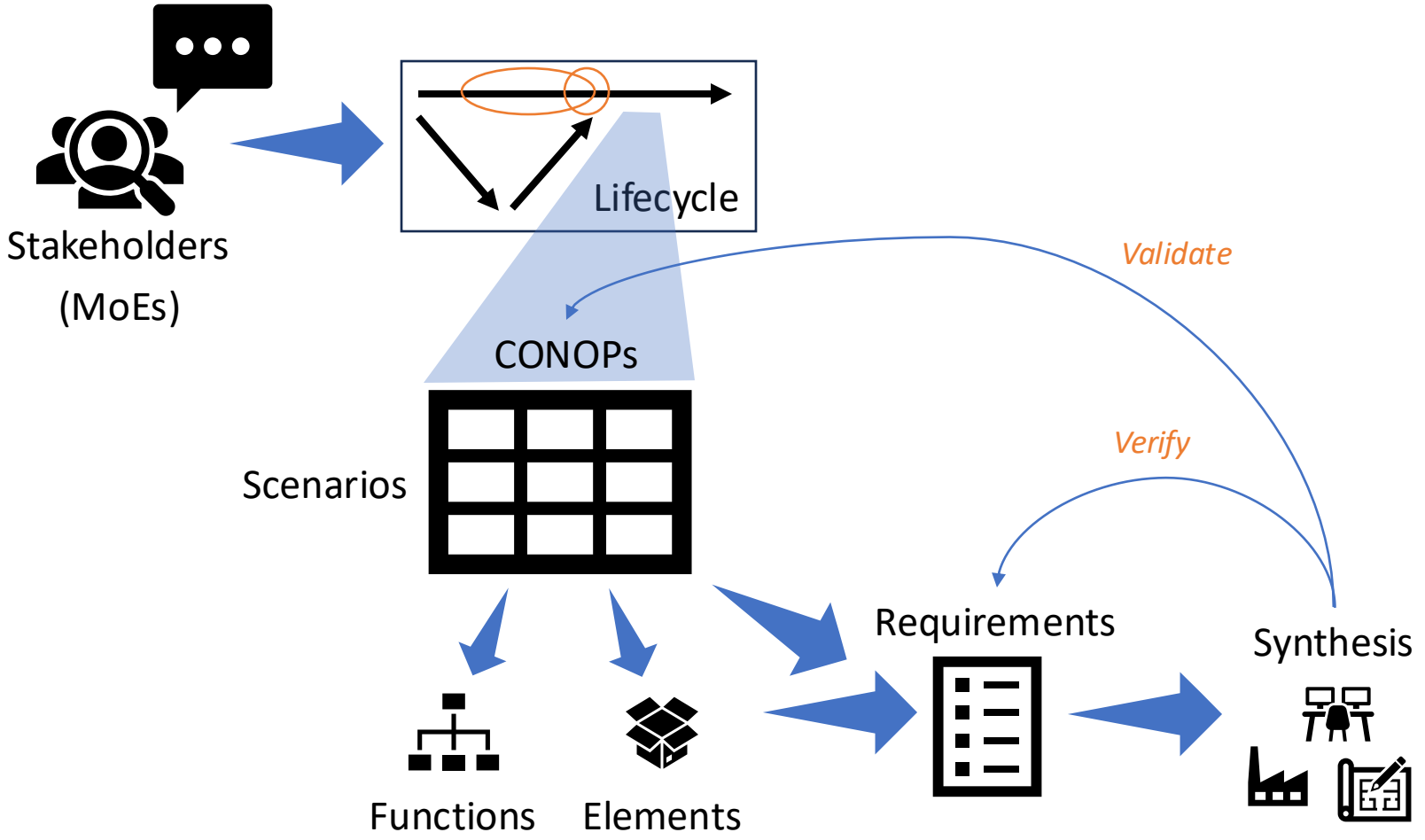

Control system cabinet
Electric power supply network
Stop road traffic
Release road traffic
Test the proper operation of the system
Discrete signal cable
Electric command cable
Vehicle crossing forbidden
Road vehicles traffic authorization
Barriers statuses
Vehicle commands
Lifting barrier
Rotation direction
Transform an electrical voltage into mechanical torque
Torque
Reduce speed and increase torque
Rotation speed
Supply voltage
Torque
Rotation speed
Module the intensity according to setpoint and speed
Activate the barrier
Electric intensity
Barrier position
Start/stop movement
Detect movement obstacles
Detect arrival in lowered stop position
Detect arrival in raised stop position
Blocked barrier
Blocked barrier
Reverse the movement
Barrier in end stop position
Determine the barrier status
Status of barriers and devices

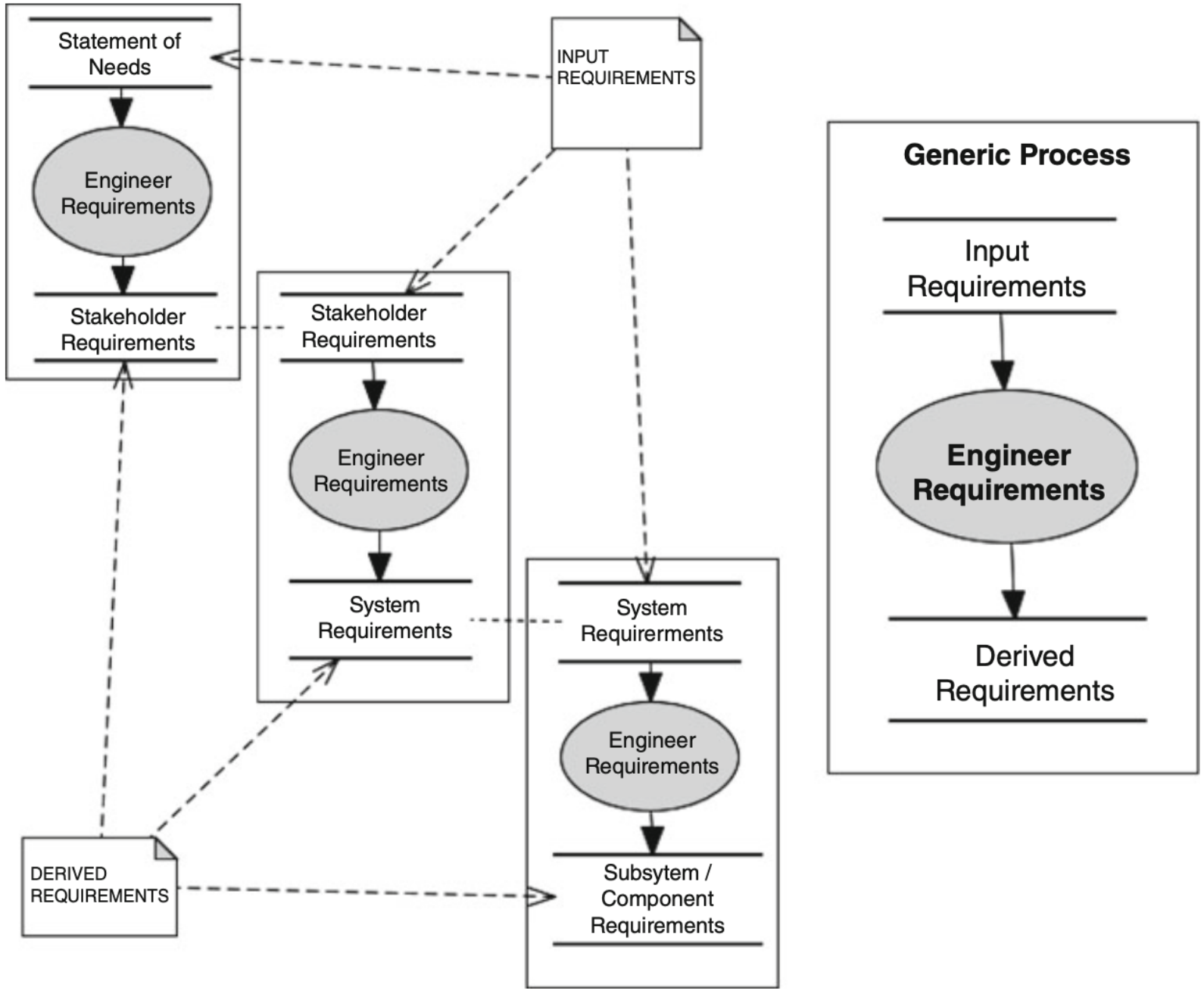
Wrapping-up


CONOPs
Pre-A
A
B
C
D
E
F
Viability Studies
Requirements
Decompose
System Design
Subsystem Design
Component Design
Assembly Integration Tests
Operation
Evaluate the organizations

X

We know the basic SE Framework




Statement of Needs
Engineer Requirements
Stakeholder Requirements
INPUT REQUIREMENTS
Stakeholder Requirements
Engineer Requirements
System Requirements
System Requirerments
Engineer Requirements
Subsytem / Component Requirements
DERIVED REQUIREMENTS
Generic Process
Input Requirements
Engineer Requirements
Derived Requirements

What is a Requirement?

statement which translates or expresses a need and its associated constraints and conditions (ISO/IEEE 15288 – 2023)

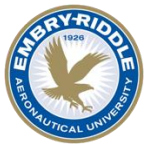
(problem domain)

Stakeholder Need (informal):

“I want the drone to fly long enough to inspect a large farm field.”

Requirement (formal, testable):

*“The drone shall have an endurance of at least **2 hours** on a single battery charge.”*



What is a Specification?

statement that describes the implementation

(solution domain)

Power shall be provided by a rechargeable lithium-ion battery pack integrated into the airframe.

What is a Requirement Specification?

The process of documenting a system’s requirements in a structured, shareable, and manageable form. (DoD Glossary)

How do we **guarantee** that we made the **system right**?

Verification – confirmation, through the provision of objective evidence, **that specified requirements have been fulfilled** (ISO/IEEE 15288 – 2023)

How do we **guarantee** that we made the **right system**?

Validation - confirmation, through the provision of objective evidence, that the requirements for a **specific intended use or application have been fulfilled**. (ISO/IEEE 15288 – 2023)

Final Considerations

Final Considerations

- **Systems Engineering is the big picture** – it provides the structured process to move from needs to solutions.
- **Requirements are the link glue** – they connect what stakeholders want with what engineers will design, build, and verify.
- **Requirements guide the lifecycle** – they support design, integration, testing, and validation across the system's development.
- **Requirements evolve** – they are elicited, analyzed, specified, and validated, always aligned with the system mission and constraints.
- **Good requirements matter** – clear, complete, and testable requirements reduce misunderstandings, rework, and cost.
- **Requirements are both technical and social** – they act as a communication tool between people and as a formal baseline for the project.
- **Our goal in this course** – to practice methods and techniques that help us write requirements that enable **successful systems**.