Systems Engineering Versus SoS Engineering

A Substitute Debate Masking a Severe Issue

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At a Glance

Flow of Thoughts	Conclusions
Systems Thinking	• Systems Thinking means thinking in scenarios • Systems Thinking is a core function in our cognitions
Implicit and Explicit Systems Engineering	• Implicit Systems Engineering is ubiquitous in vertebrates (scenario understanding – motivation – insight – creative solution) • Explicit Systems Engineering with workshare, specialisation and standardisation is a specific human trait
System-of-Systems Considerations	• Originally, Systems-of-Systems identifies a distinct system level in military procurement • Systems-of-Systems Engineering is less concentrated on development-on-demand than employing existing assets
Systems Engineering as a Philosophy of Being	• Systems Engineering as a Philosophy of Being fosters an unrealistic Perfect World Illusion

Systems Engineering as a Philosophy of Becoming

Recommendations

- Reconsider Requirements Engineering in the context of marketing and motivation psychology
- Consider the role of Producing Enterprises in market economies
- Emphasise the role of Conceptual Systems Engineering in Business Planning

Human Perception – Visual Perception

What we don't see

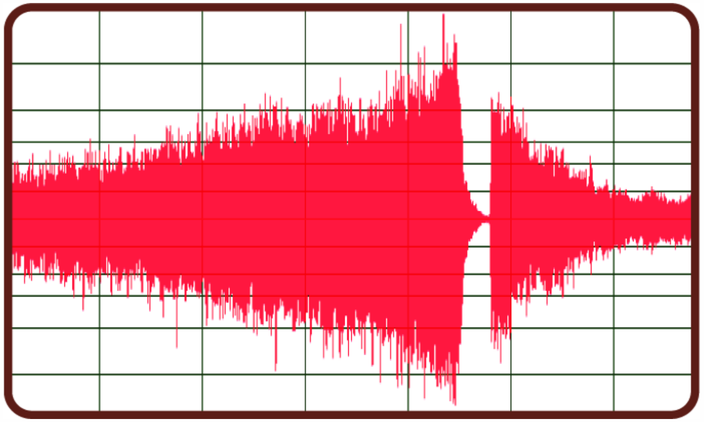
- A small colourful cone area at the centre and a grey-scaled image offsite with a black spot

What we see

- A colourful road traffic scenario with pedestrians, cars, busses and traffic lights etc.

Human Perception – Audio Perception

What we don't hear



- A mix of audio waves

What we hear

- Sounds
- Voices
- Melodies

Conclusions

- What we perceive are not raw sensory data like a screenshot or a mixture of audio wave frequencies
- What we actually see are things with visual shapes. What we hear are noises, voices and sounds
- All the individual perceptions are further merged cognitively into scenarios of what is and what may happen
- As we always think in scenarios, we always are thinking in systems
- Systems thinking is a core function in our cognitions

E. B. Goldstein: Sensation and Perception. 2010.

System Terminology

Traffic Scenarios

- Scenarios are less characterised by their constituents than by resulting behaviours within these scenarios
- We may denominate scenarios by particular terms like traffic
- The term system is just a placeholder term for traffic as thing is a placeholder term for a car
- The term system may also be used as placeholder term for a car having in mind that the car's behaviour emerges from the functions of its building blocks
- The term system may be applied in a recursive manner resulting in multilevel system architectures: Systems comprise system elements that themselves may be denominated as systems

ISO 15288: System Life Cycle Processes. 2015.

Implicit Systems Engineering

Implicit Systems Engineering starts with the usage of tools

- A New Caledonian Crow understands the scenario:
  A caterpillar is unreachable in a crack of the wooden trunk
- The crow is motivated to get this protein-rich food
- Due to an act of insight it invents and manufactures a hook for levering the caterpillar out of the crack
- Other crows learn by imitation to manufacture hooks as well

- Regarding other tools, continuous design optimisations have been observed
- In distant living populations, the optimisations take different directions indicating signs of cultural distinction

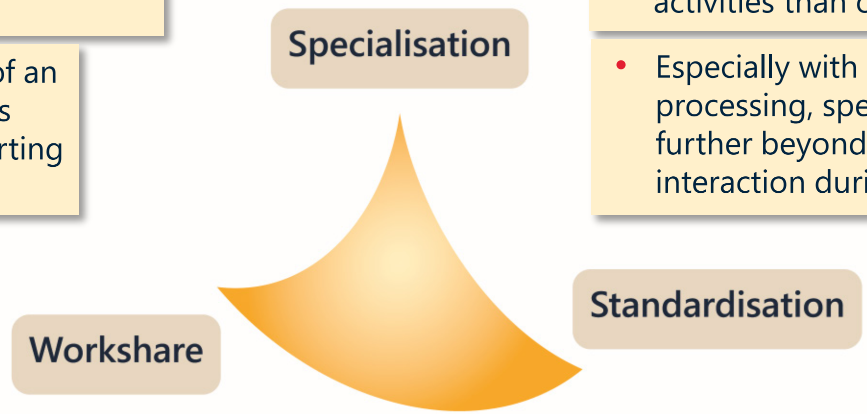
The Human Path of Growth and the Evolution of Explicit Systems Engineering

Implicit Systems Engineering

- Learning by imitation in an master and apprentice arrangement is still important for humans
- The unique human capability of an argumentative language allows additional explanations supporting learning by imitation
- In addition, humans are able to improve their knowledge by learning from theories alone

Specialisation

- Specialisation may have started with some individuals more talented for certain activities than others
- Especially with irrigation systems and metal processing, specialisation progressed further beyond the need for direct social interaction during workshare execution



Workshare

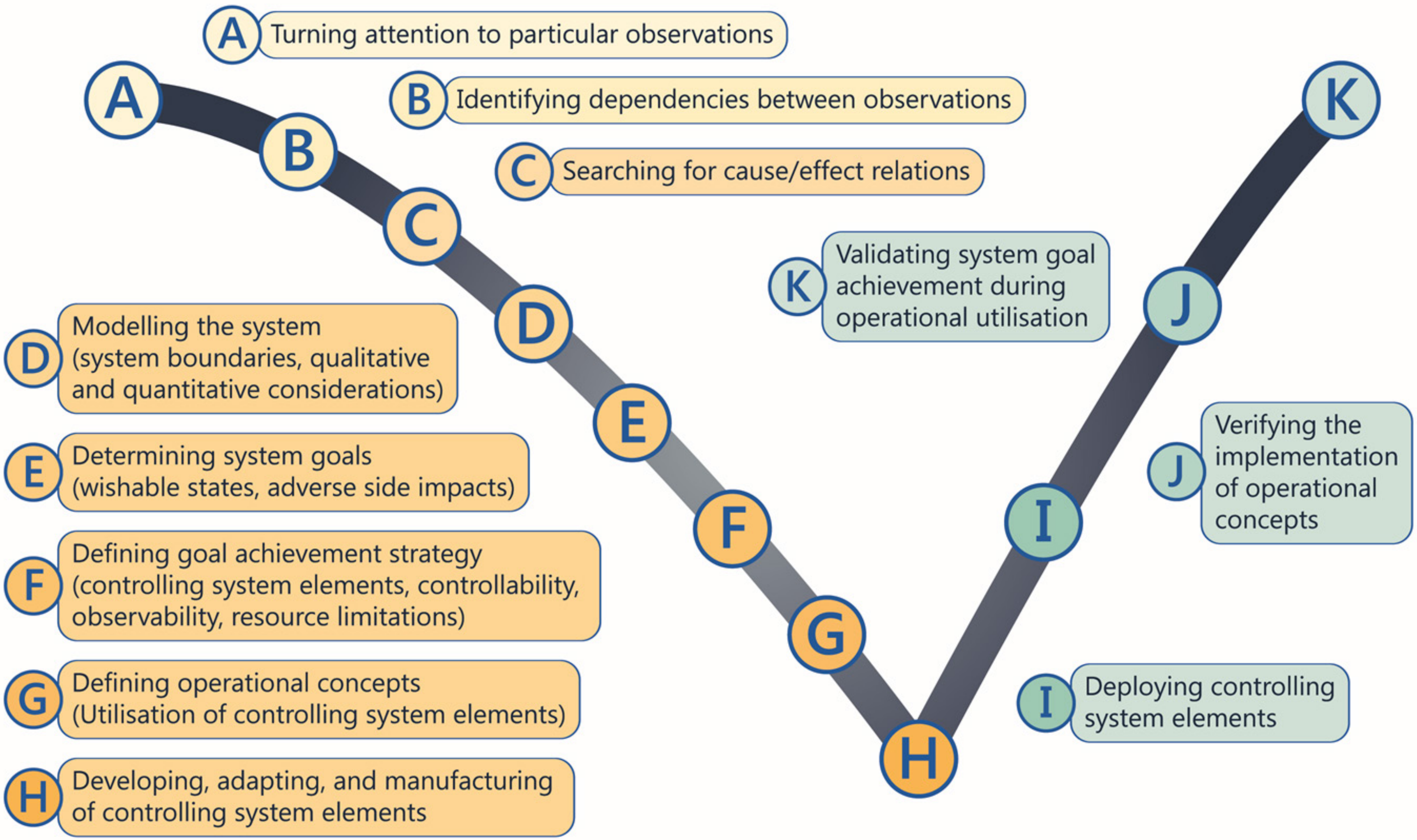
- The mutual enhancement of argumentative language and social interaction provides humans with an evolutionary advantage
- In consequence, human populations tend to enter a path of growth
- When the satisfaction of basic needs is achieved in a sustainable manner, the surplus provides opportunities to consider the satisfaction of more advanced needs.

M. Tomasello: A Natural History of Human Thinking. 2014.

Standardisation

- Standardisation simplifies the workshare
- Standardisation may start with standards for nuts and bolts
- In mature societies, standardisation ends up in the fixation of technical, economic and societal architectures

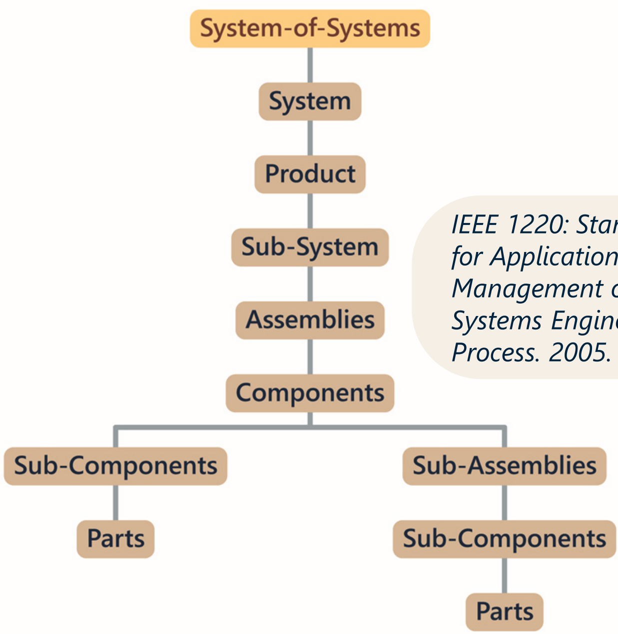
The Scope of Systems Engineering



System-of-Systems Considerations

The Origin of the Term System-of-Systems

- When the term SoS has been coined it was a usual practice to designate particular system architecture levels by dedicated terms



IEEE 1220: Standard for Application and Management of the Systems Engineering Process. 2005.

- According to this logic it was straight to call the level above the system level system-of-systems

Why is the term System-of-Systems still in use?

- The discussion of Human Perception and Systems Thinking has explained why a recursive terminology scheme of systems decomposed in system elements that may be denominated systems in themselves again makes the term System-of-Systems redundant
- When applied in a reductionistic manner, Specialisation directs artisanship downwards the system architecture increasing the vulnerability risks against architectural changes
- Debates around Systems-of-Systems are always concerned with an impression that Systems Engineering – as it is codified – is not appropriate to cope with the real dynamics of scenarios, system architectural changes and market economies in all application scenarios

M. Henshaw, P. Brook, J. Dahmann, D. Scheithauer: LS SCI-276 – Systems of Systems Engineering for NATO Defence Applications. 2015.

F. Baldauf, J. Heinrich et alt.: System-of-Systems Engineering in Deutschland: Bestandsaufnahme und Ausblick. TdSE 2022.

Systems Engineering as a Philosophy of Being

Historical Systems Engineering Context

- Norbert Wiener's (1894-1964) feedback theory enabled system models of unprecedented complexity

N. Wiener: Cybernetics or, Control and Communication in the Animal and the Machine. 1948.

- Success in early operations research during World War II demonstrated the advantages of multidisciplinary cooperation
- The academic-military-industrial complex established procurement rules following a management by command and control style
- The American style of mass production was transferred to the development of innovative systems

R. Schwartz Cowan: A Social History of American Technology. 1997.

Concluded Systems Engineering Practices

- Systems Engineering focussed as multidisciplinary endeavour for generating innovative system concepts
- Systems Engineering was successful in reducing overall risks, but could not eliminate all risks
- A first-time-right approach to systems engineering was declared as the gold standard with the focus on requirements and contracts
- In consequence, only conceptual systems engineering was assumed to be the creative part of systems engineering and all other development activities were deemed to be a kind of implementation issue only

Supporting Evidence

- At last year's SWISSED22 themed "From Design to Reality – Walking up the V", just four presentations were considering system integration, validation and verification plus a keynote recommending a first time-right-approach concentrating on the left leg of the V, and not to bother too much with activities on the right leg of the V
- The well known inconsistency between the requirement definitions in ISO 9000 and ISO 15288 and the adverse impact on the understanding of validation and verification has never been corrected so far

Definitions according to ISO 9000 und ISO 15288

	ISO 9000:2015	ISO 15288:2015
Requirement	Need or expectation that is stated, generally implied or obligatory	Statement which translates or expresses a need and its associated constraints and conditions

- Consequently, organisations with a certified Quality Management System according 9001 may use two quite different requirement definitions in the same enterprise context

Validation	Confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled
Verification	Confirmation, through the provision of objective evidence, that specified requirements have been fulfilled

- The definition for Requirement has become restricted in Systems Engineering
  - ➢ The definition for Verification remains understandable
  - ➢ The definition for Validation loses its meaning, and is not anymore distinguishable from Verification

Systems Engineering as a Philosophy of Becoming

The Main Difference Between Manufacturing and Development

- In production, the configuration basis and the manufacturing process are given upfront and conforming products and services are verified in accordance with these product standards

♦

- In development, the appropriateness of the initial requirements needs always be controlled in a feedback loop by validation activities leading to rather high development dynamics increasing with the level of innovation and system complexity

General Remarks

- The human capabilities for forecasting complex future scenarios are rather limited in general
- The engineering of innovative systems is interlocked with re-shaping existing language and generating new language
- The perfectness level of Gestalt qualities at the end of development is higher than at the beginning
- Successful systems engineering is a one-way road towards perfection, fully in the literal sense

Recommendations for a Systems Engineering Transformation Towards a Philosophy of Becoming

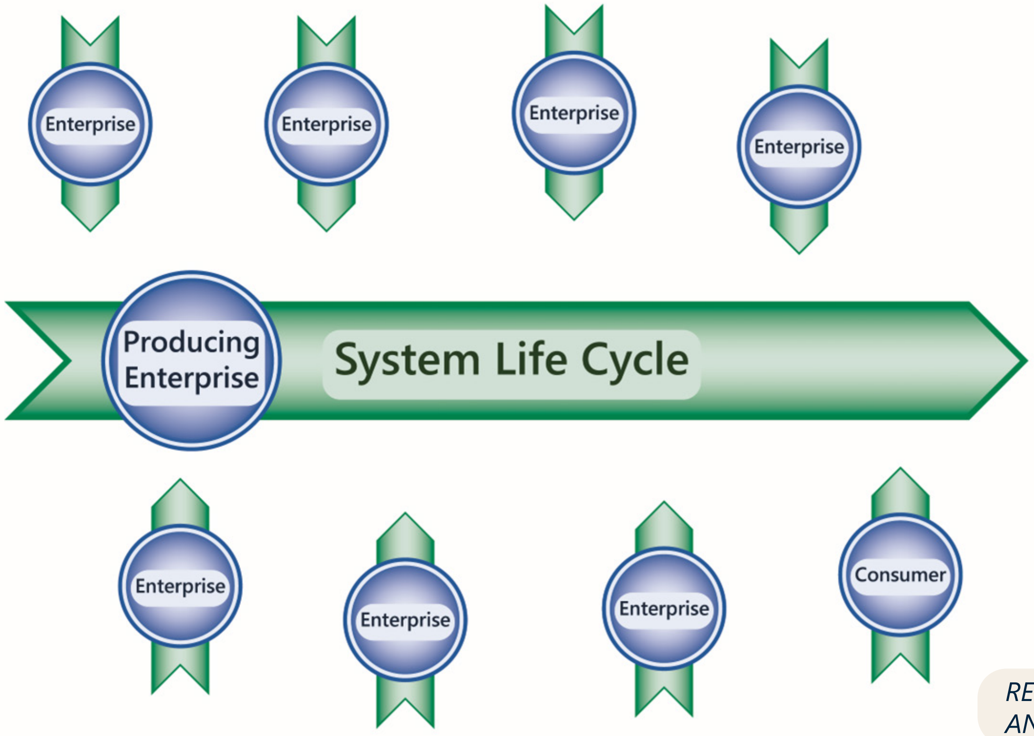
Heckhausen, J., Heckhausen, H.: Motivation und Handeln. 2010.

- Reconsider Requirements Engineering reviewing marketing terminology and motivation psychology

P. Kotler, K. L. Keller: Marketing Management. 2012.

- Consider Systems Engineering in a Market Economy with emphasis on the role of Producing Enterprises
- Consider the integration of Conceptual Systems Engineering with Marketing and Business Development

The System Life Cycle and the Producing Enterprise



The Producing Enterprise

- The Producing Enterprise takes an important role regarding the offered products and services
- The Producing Enterprise is responsible for its products and services with respect to liability and safety
- The role of the Producing Enterprise is missed by systems engineering standards as quality management standards operate with a rather unspecific term organisation with no particular reference to legal requirements

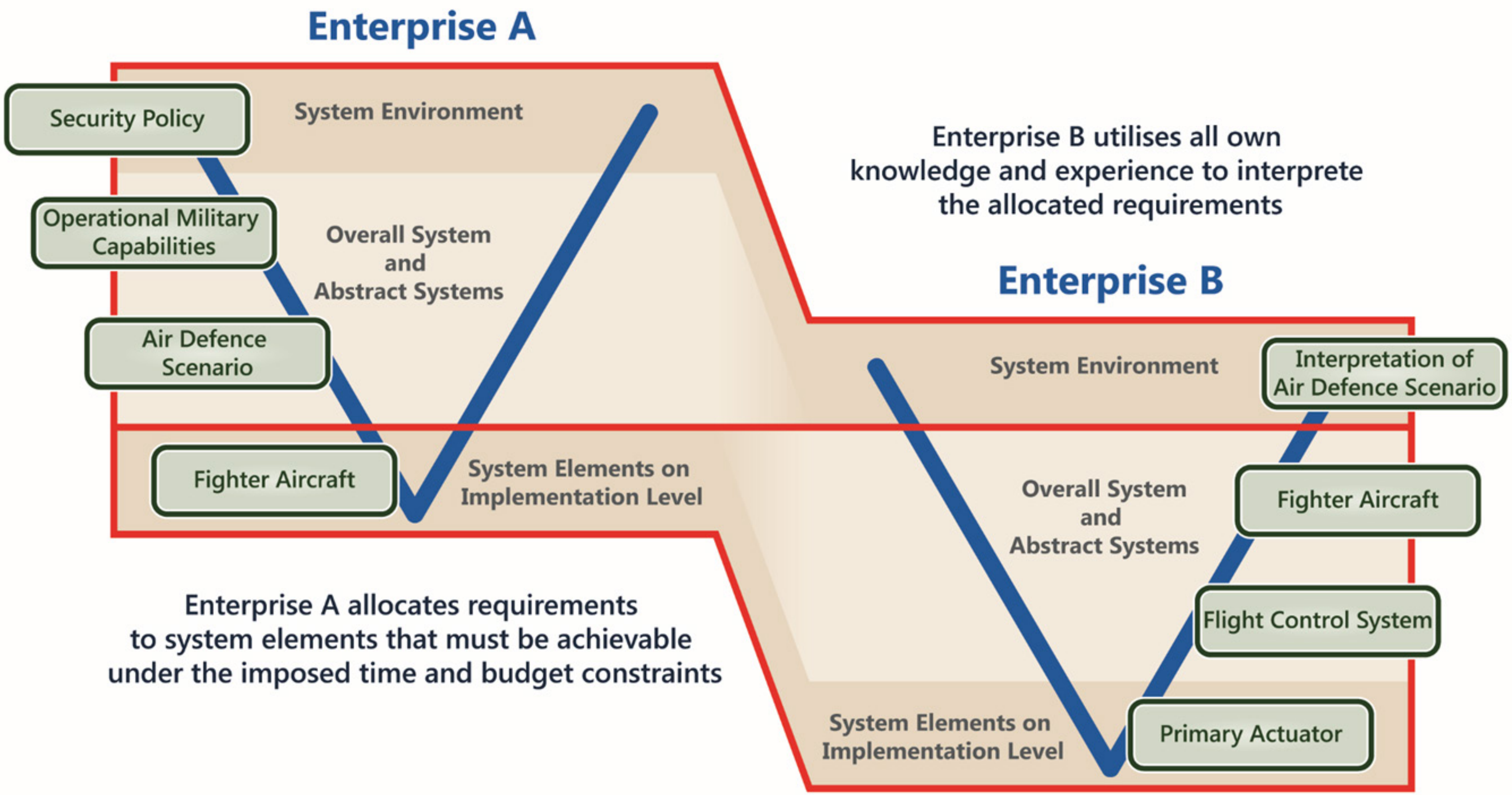
REGULATION (EU) 2023/988 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 10 May 2023 on general product safety

Council Directive 85/374/EEC of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products

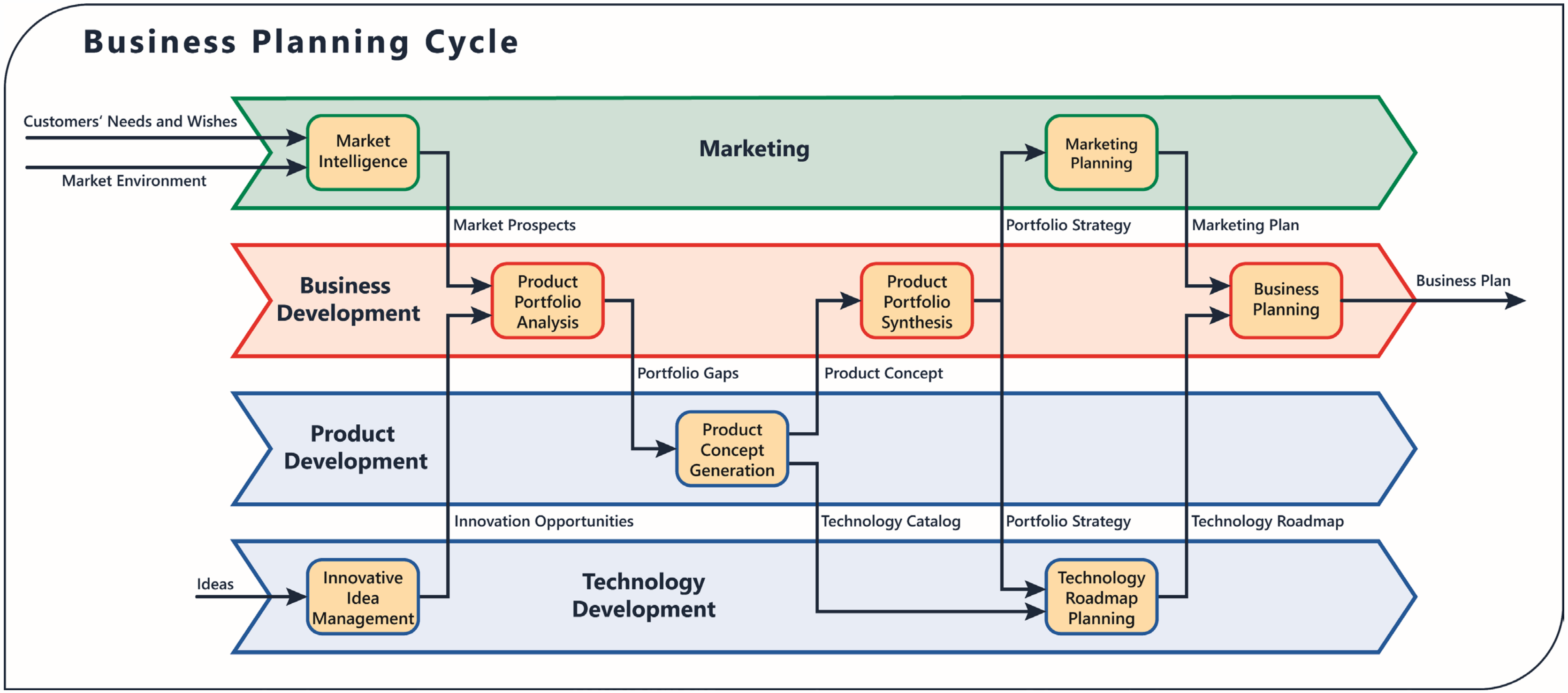
The System Life Cycle in a Market Economy

- The System Life Cycle is a cut through an economy along the life cycle of a particular product or service
- Enterprises interact with the System Life Cycle in various roles like supplier, developer, merchant, customer, operator, maintainer or disposer by their own products and services

Enterprise Workshare



The Role of Conceptual Systems Engineering in Business Planning



- Business Planning is an enterprise activity using general budgets
- A Business Planning Cycle may run at least once per year
- Product Concepts may be matured over longer time periods

Thank You

for your attention

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H·I·T·S Engineering

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