System Interfaces and System Interoperability in a System-of-Systems Context

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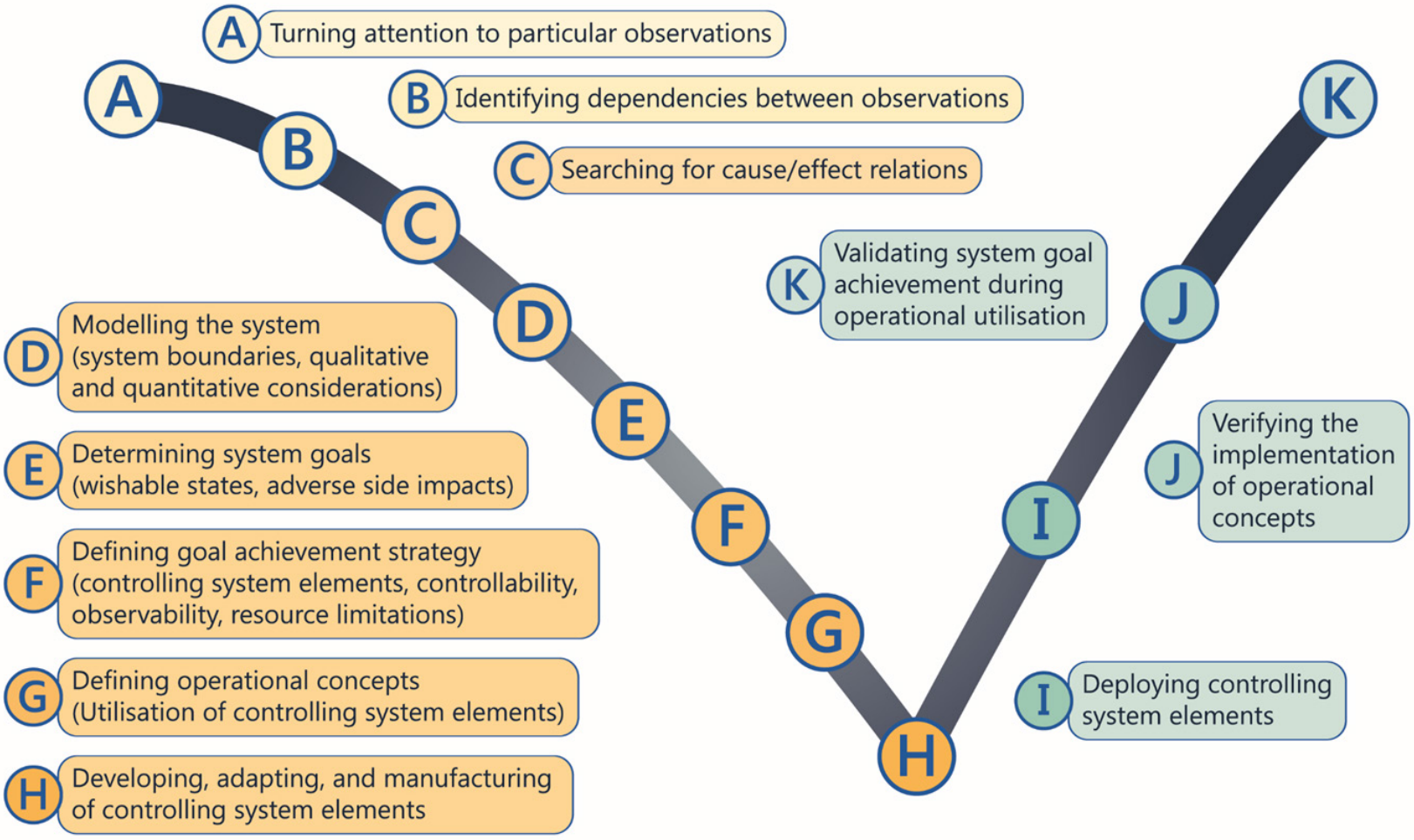
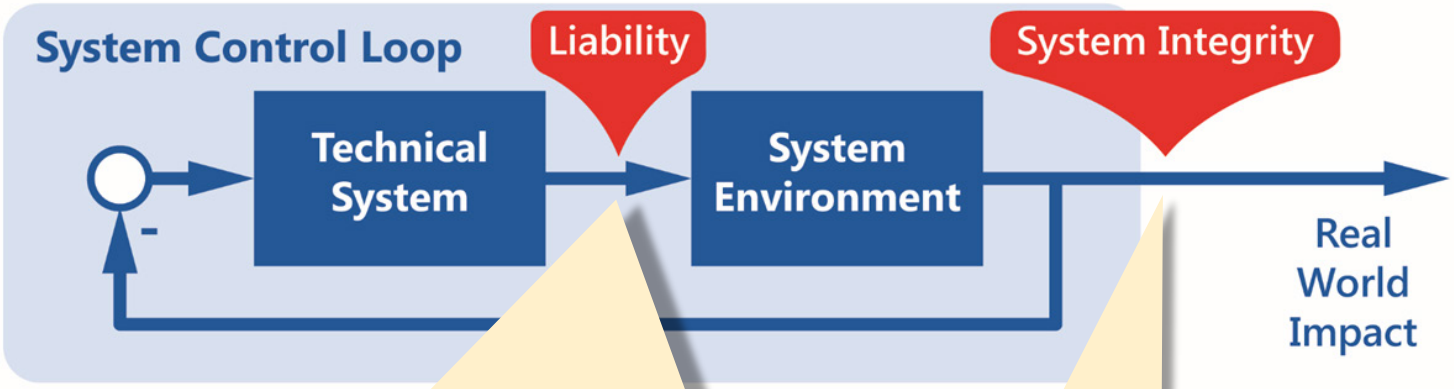
- Specialisation
- Workshare
- Standardisation
- The System-of-Systems Context
- System Interoperability
- System Interfaces
- Conclusions

From Problem to System Solution



The System Control Cycle



- Liability regarding safety, security etc. from the perspective of the producer of the Technical System
- In case of intended and foreseeable modes of operation, the Technical System shall neither generate personal or material damage nor pecuniary losses
- Failures in the Technical System shall do no damage to the System Environment

- System behavior complies with intended expectations
- Interpretation of the System Environment as an open system

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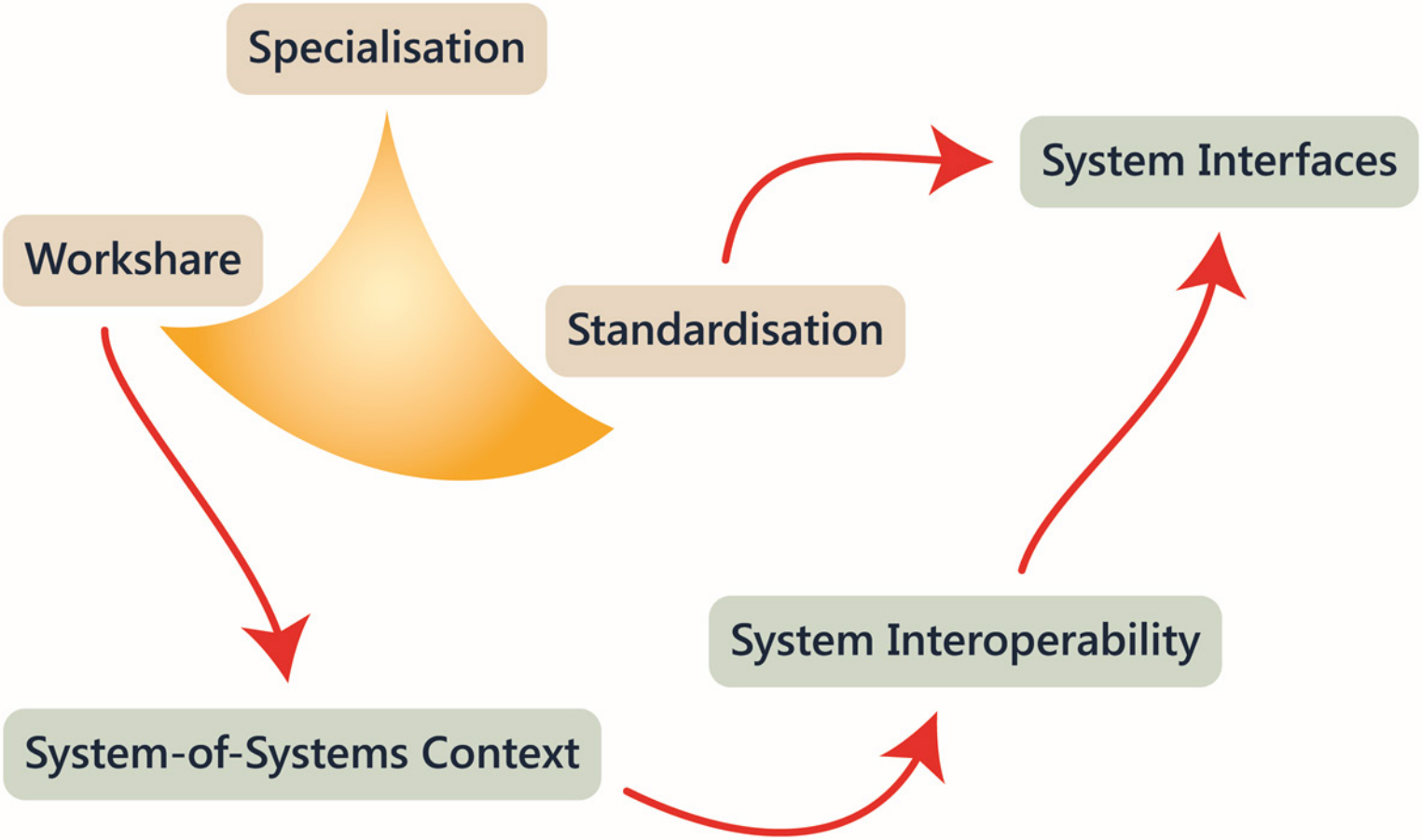

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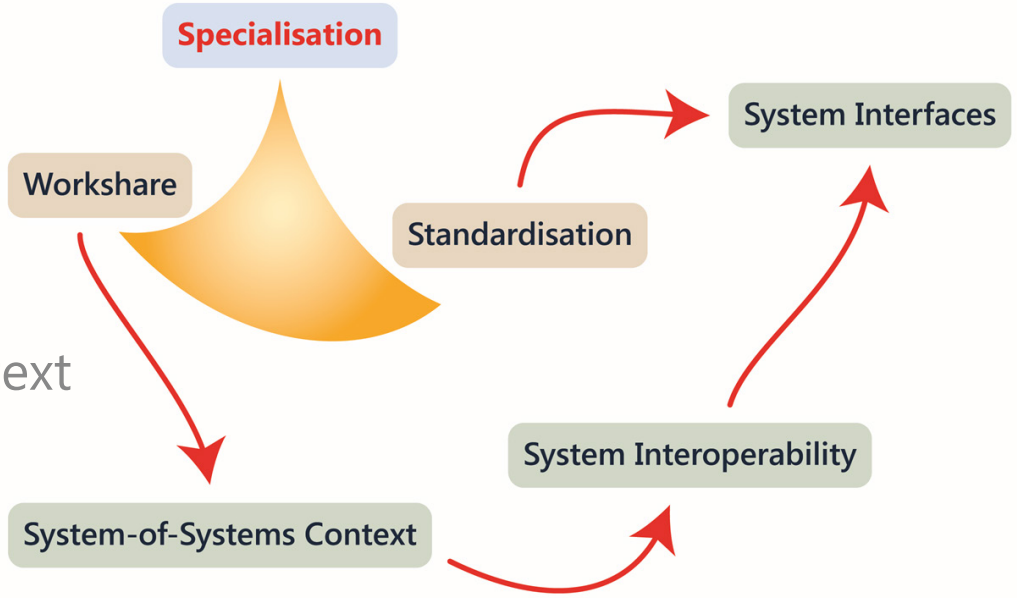

Specialisation – Opportunity and Challenge

- Humans are a unique species that share collective intentionality
  - Foundation for specialisation and workshare
- Discipline specific terminology and language
- Distinctions meaningless to other disciplines
- Discipline specific problem solutions not valued and consequently not considered
- Non-acceptance of necessity for corrective actions for problems not found and understood by other disciplines

  - ***As an integrative discipline, systems engineering has to provide solutions for all these challenges***

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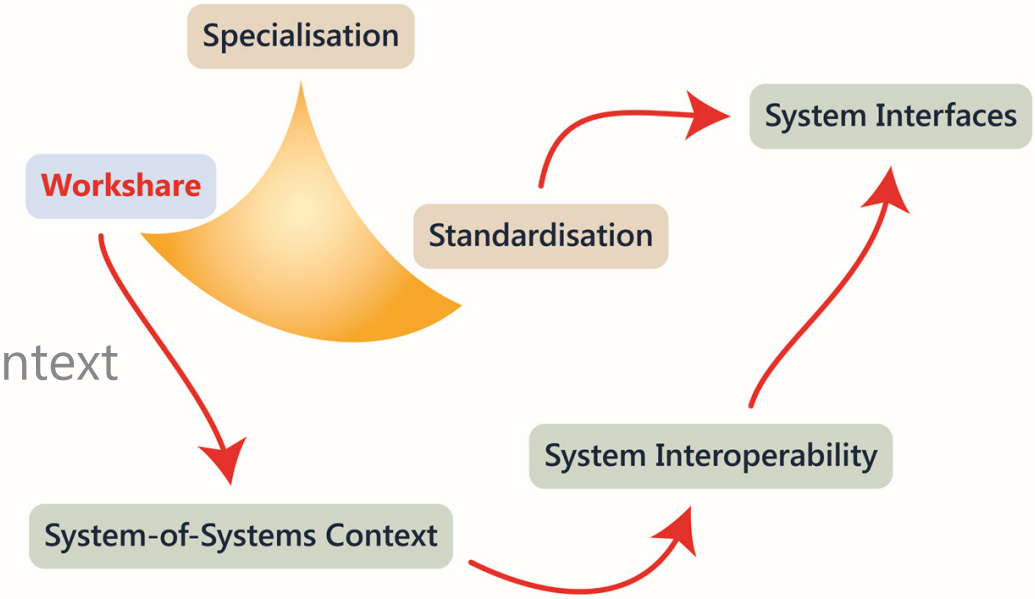
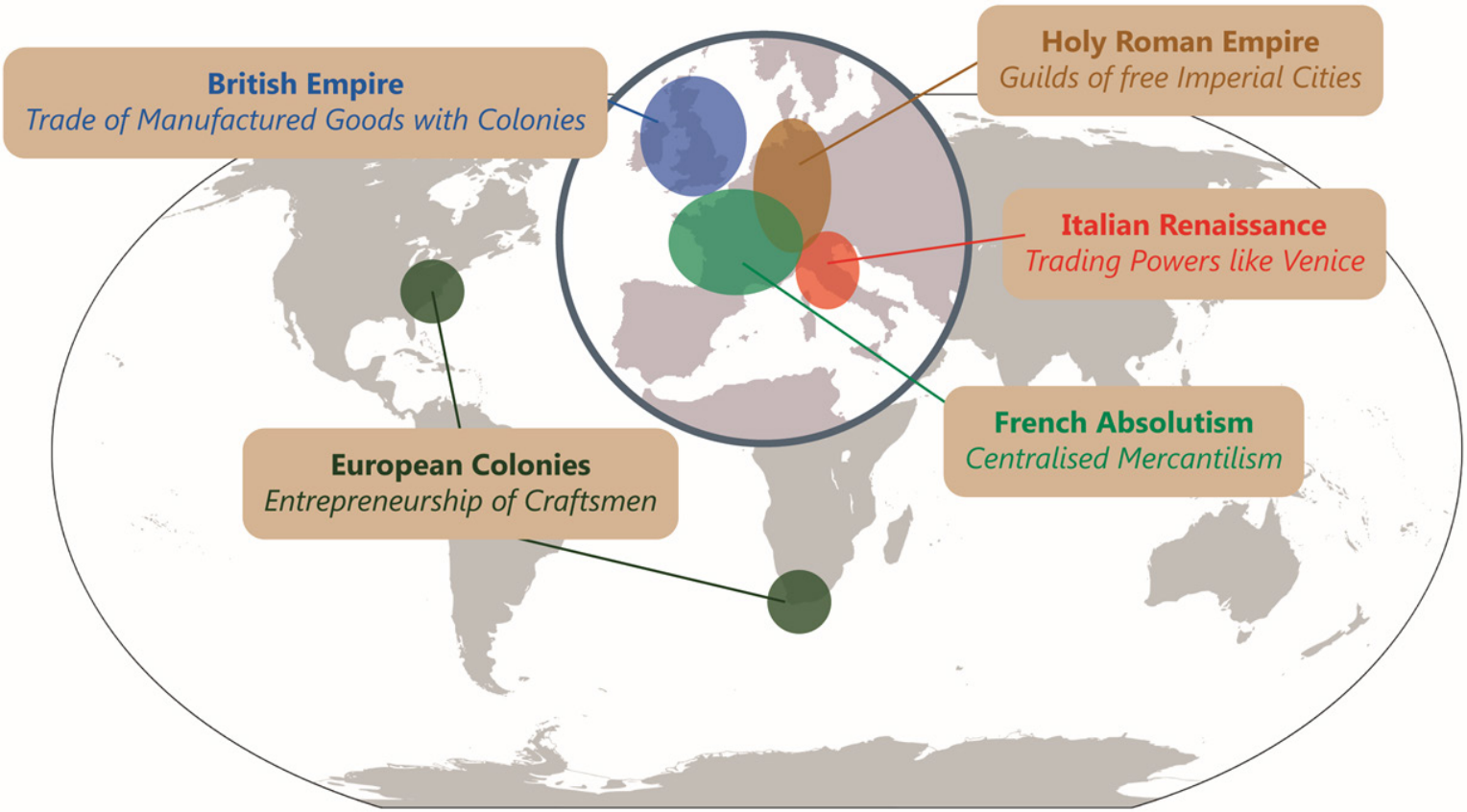


A Historical Review on the Organisation of Workshare



Workshare Organisation Solutions from Greenfield to Market Opportunistic Approaches

- Nearly endless value generation depth
- New technologies to be invented
- New infrastructure to be established

- All constituents (products, services, and infrastructure) available
- New application of existing products
- Innovative idea to integrate existing products

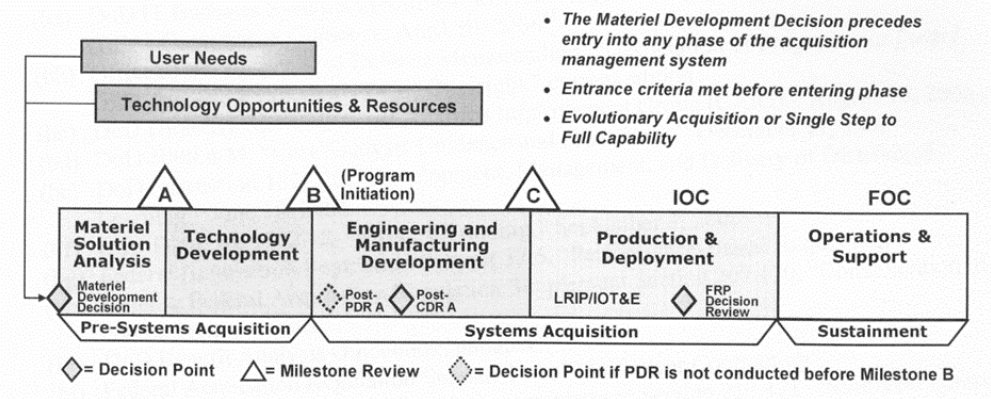
➢ ***In reality, systems engineering is neither applied to pure greenfield nor to pure market opportunistic approaches***

Evolution of NATO Procurement Policies

- Up to the 1990s, procurement policies of NATO and its member countries followed widely a greenfield approach
- Many technologies developed for military use became dual use products
- In 1994, the US Secretary of Defence, William Perry, announced a policy change to rely on COTS in military procurement whenever possible

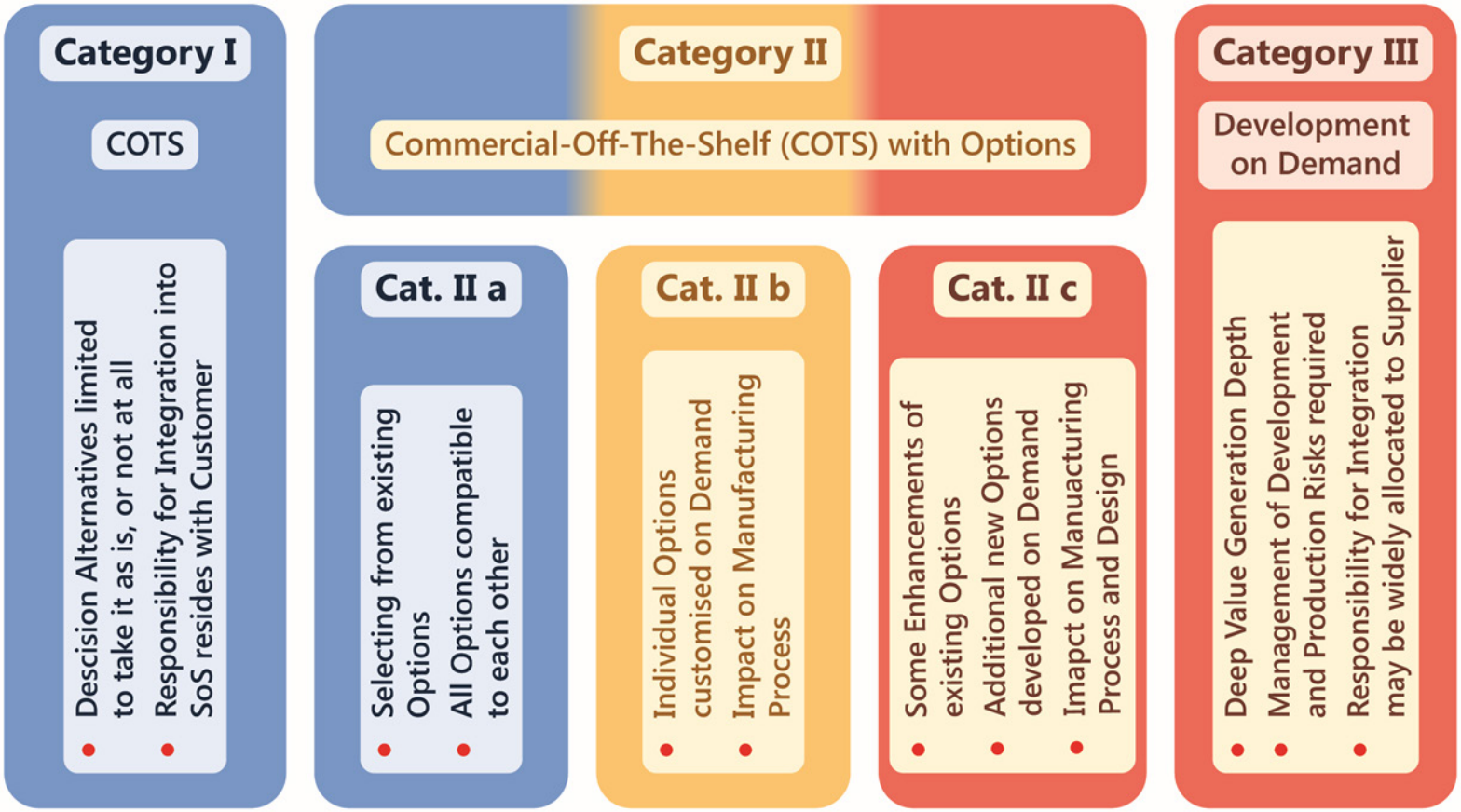
Procurement Policies Since 1994

- NATO and its member countries have taken quite different directions since
- In the US, the procurement policies are still modelled close to the old greenfield approach



- In Germany, the definition of capabilities on the SoS level has precedence over technology and product development
- A product taxonomy for guiding procurement policies in the range from greenfield to market opportunistic approaches does not exist

Product Taxonomy



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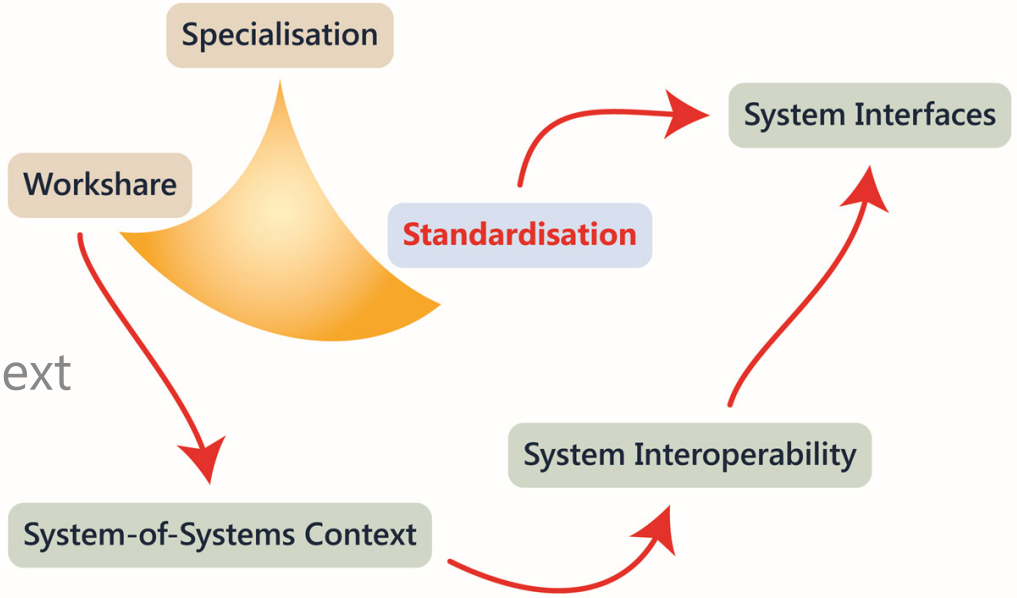
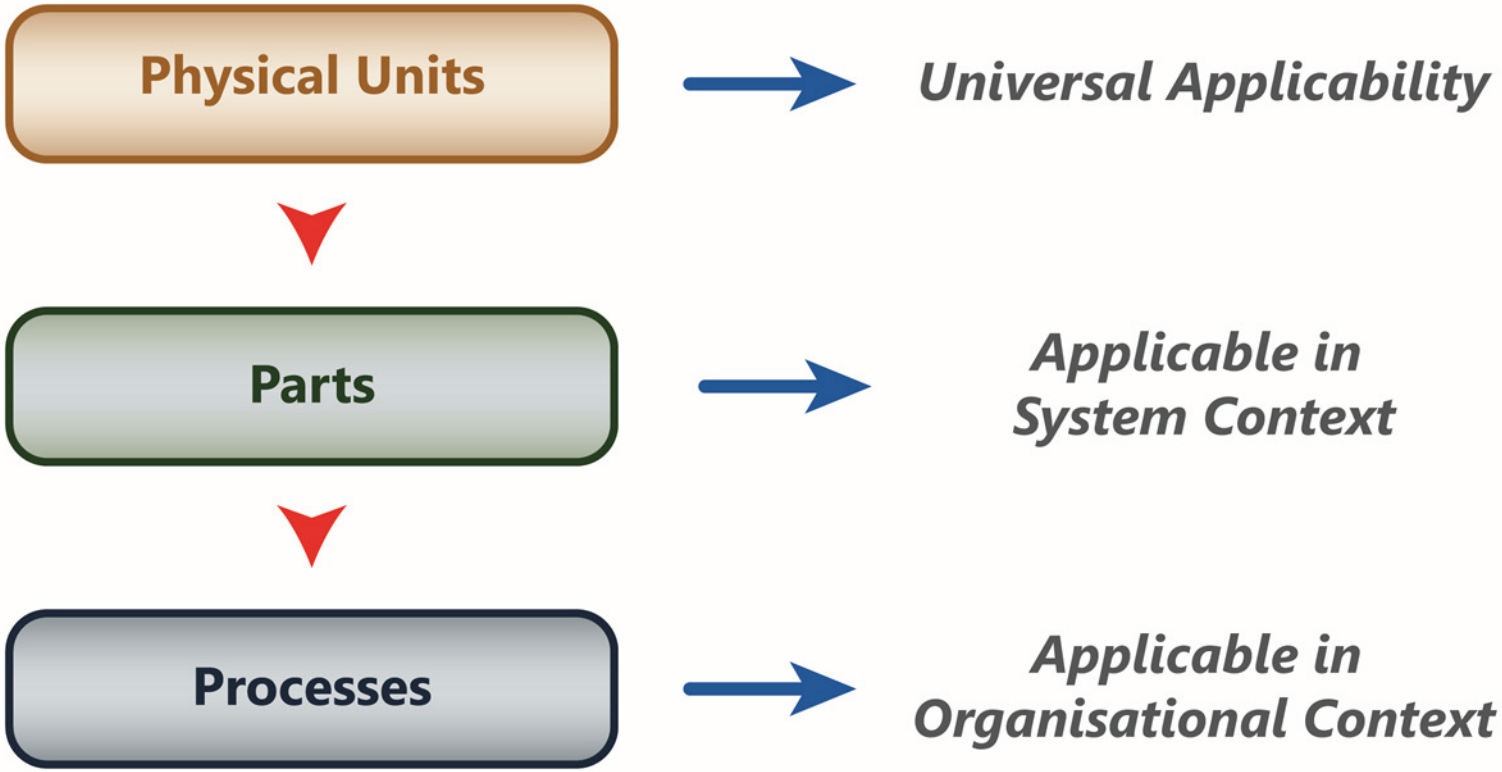


Standardisation



Limitations of Standardisation

- Standards are valid in a certain context
  - They represent the knowledge and experience of the organisations and individuals involved in the standardisation process
- Standards codify the status quo, they don't encourage innovation
- Quality of standards may vary
- Using several standards in conjunction may lead to incoherence
- Standards may have discriminating effects
  - Intellectual property rights
  - Demanding compliance with a huge amount of standards may be a barrier for new players entering a market

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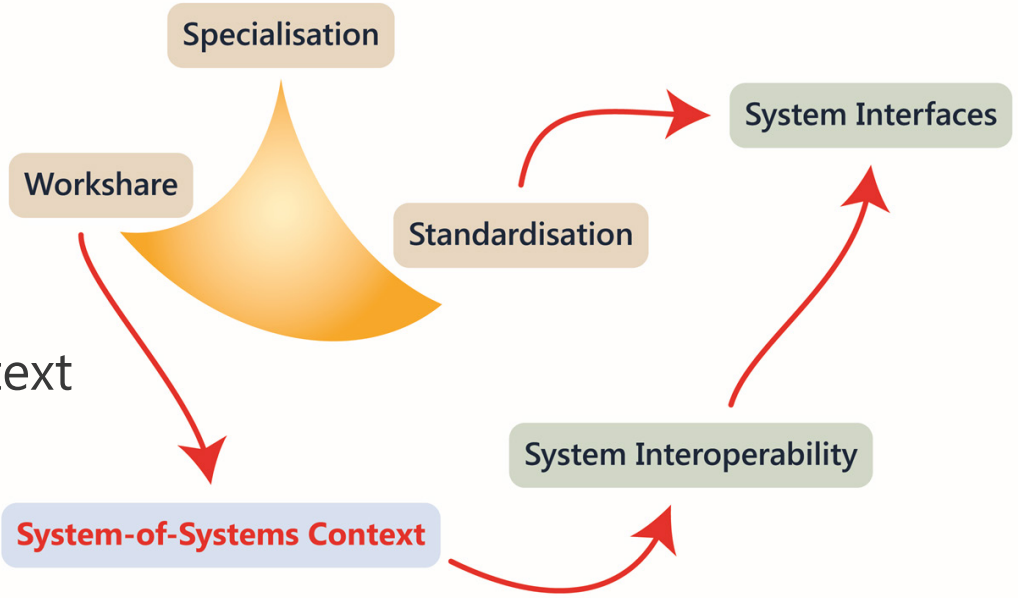
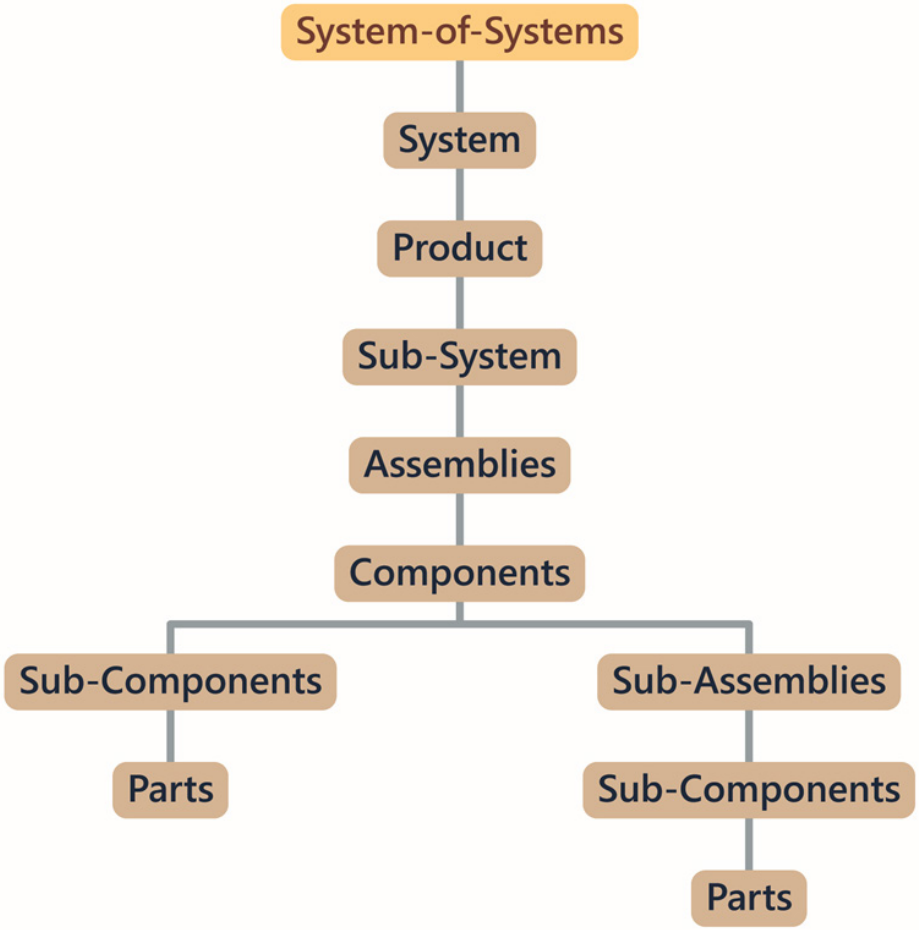
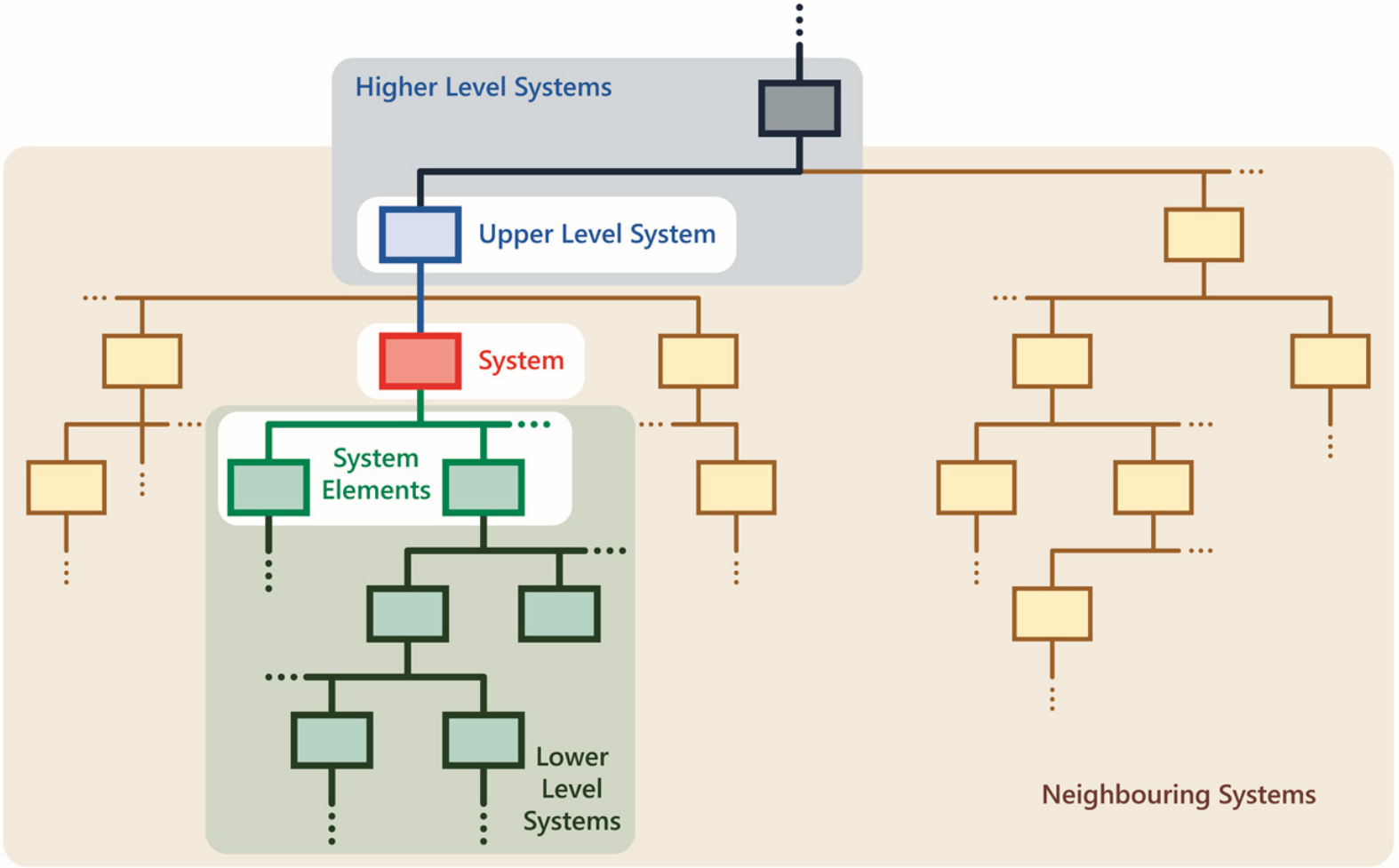


System-of Systems – A Simple Definition



- When the term SoS has been coined it was a usual practice to designate particular system architecture levels by dedicated terms
- According to this logic it was straight to call the level above the system level systems-of-systems
- This practice has more or less be abandoned in favour of recursive naming schemes

Recursive Scheme of System Terminology



The System-of-Systems Context

- The SoS context is determined by organisational segregation
  - With the procurement of COTS systems, SoS integration could not be delegated anymore to suppliers
  - SoS engineering became a new demand
  - SoS considerations extend further into SoS with weak central control during operation
- The advances in information technology promised benefits for better SoS coordination and management
  - Emergent features and behaviours became available for SoS
  - Network centric warfare
  - SoS ways of thinking evolved in non-military domains as well

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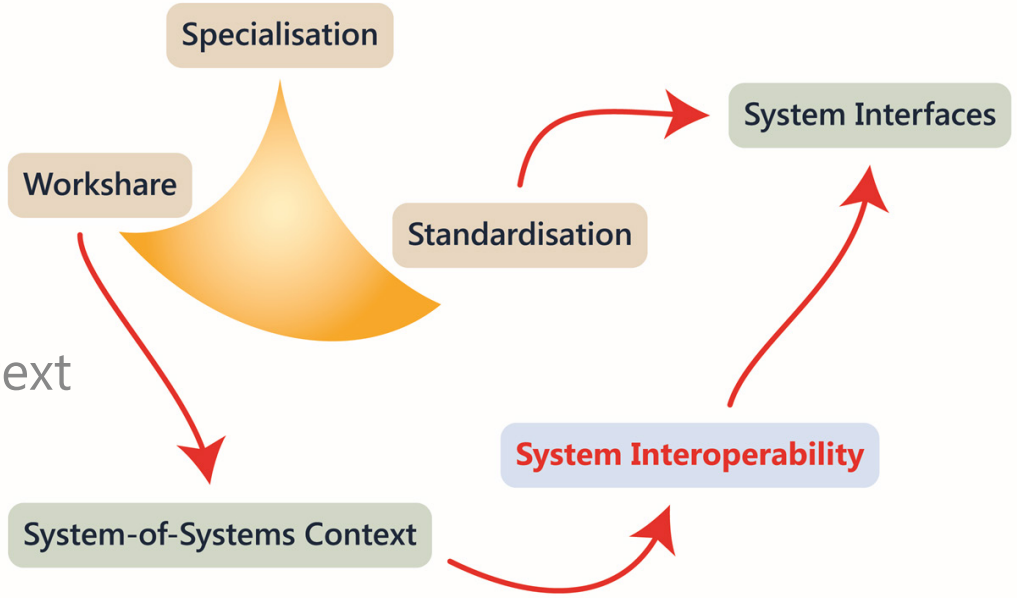

Traditional System Interoperability Provisions

- Before the IT revolution military operations relied mainly on people and processes utilising the procured technical systems
  - This military SoS was not anticipated as a “technical” system
- System interoperability is not concerned with information technology only
  - Cross-servicing capabilities
- STANAGs (Standard Agreements) comprise a wider range of content
  - Cross-servicing capabilities *(STANAG 2121: Cross-Servicing of Medical Gas Cylinders)*
  - Specific military technical solutions *(STANAG 3838: MIL-Bus)*
  - Information technology focused solutions *(STANAG 5524 incl. ADatP 34: NATO Interoperability Standards and Profiles)*

NATO Interoperability Environment

- NAF – NATO Architecture Framework
  - Current Version: 3.1
  - Started as NC3AF (NATO C3 Architecture Framework)
- NISP – NATO Interoperability Standards and Profiles
  - STANAG 5524 and ADatP 34
  - Principle source of procedures, architectural concepts, data (standards and products) and their relationships from which the technical view according to the NAF may be constructed
- NIETI – NATO Interoperability Environment Testing Infrastructure
  - Envisaged, but current status is unknown to author

Interoperability Degrees

- Degree 0 – Isolated Interoperability in a Manual Environment
- Degree 1 – Connected Interoperability in a Peer-to-Peer Environment
- Degree 2 – Functional Interoperability in a Distributed Environment
- Degree 3 – Domain Interoperability in an Integrated Environment
- Degree 4 – Enterprise Interoperability in a Universal Environment

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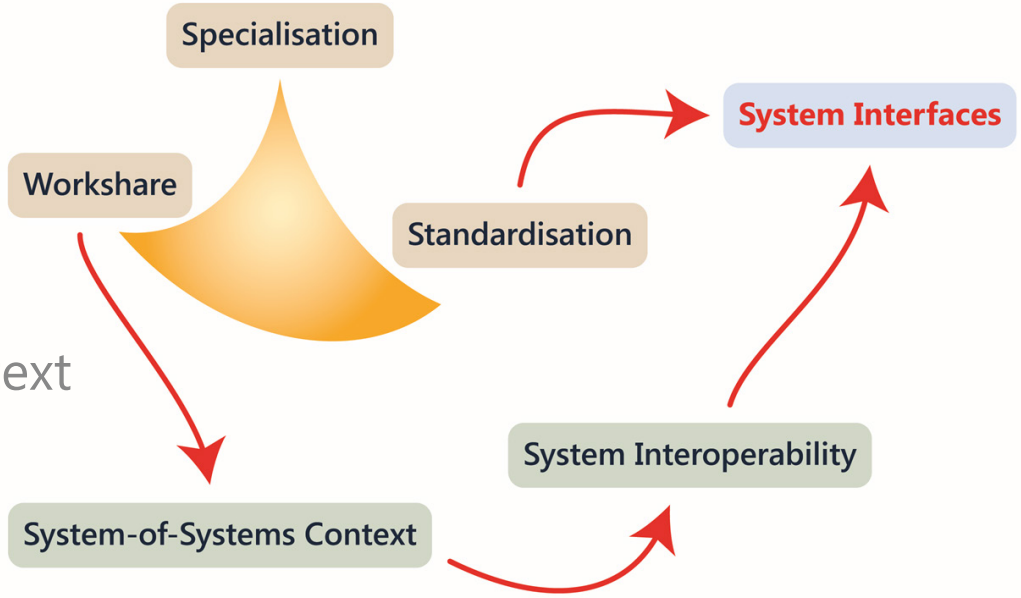
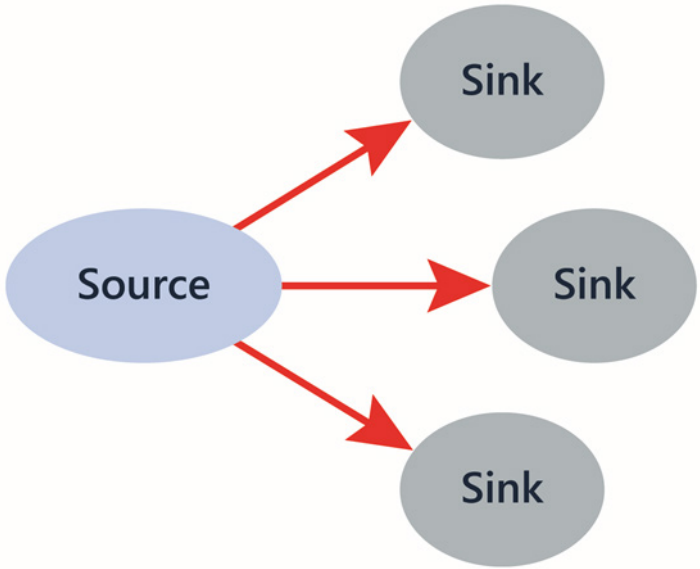
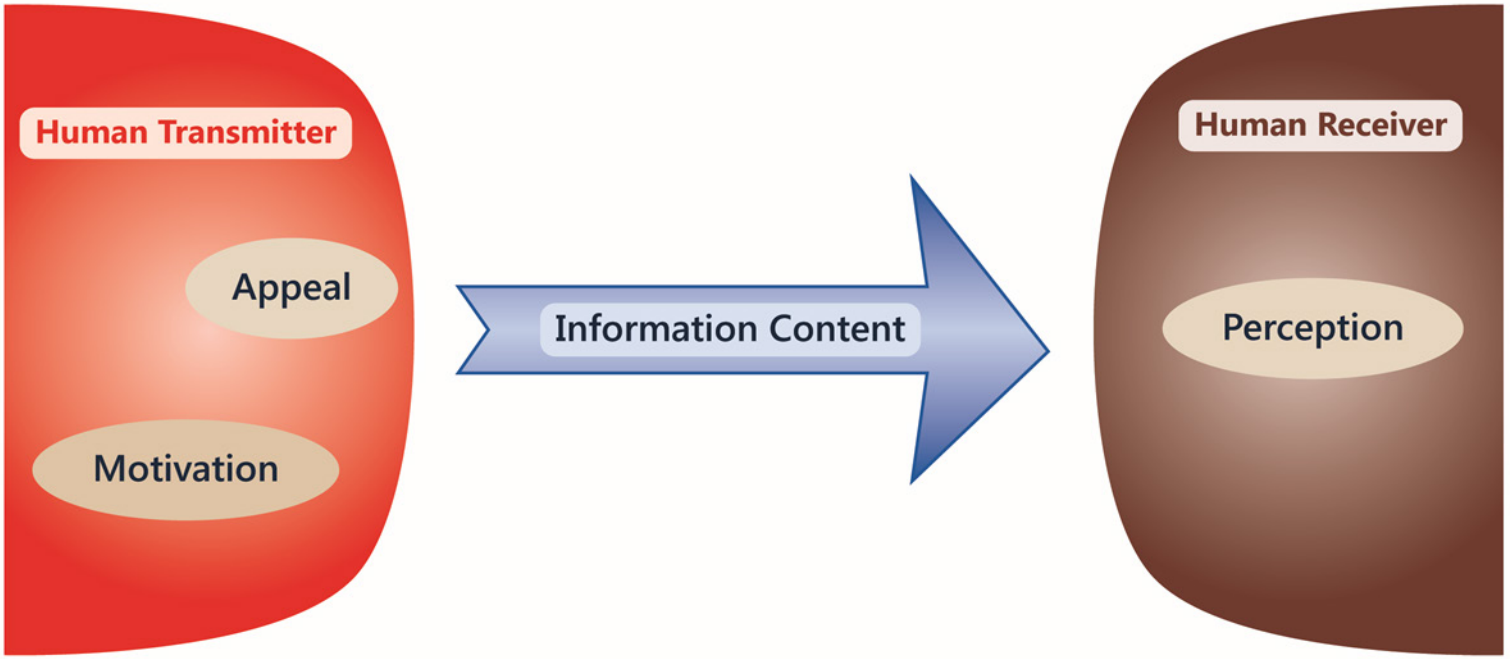


Information Interfaces

- System interfaces are the results of the architectural decomposition throughout the whole system architecture
- For system interoperability considerations, interfaces are abstracted as information flows flowing from one source to one or multiple sinks



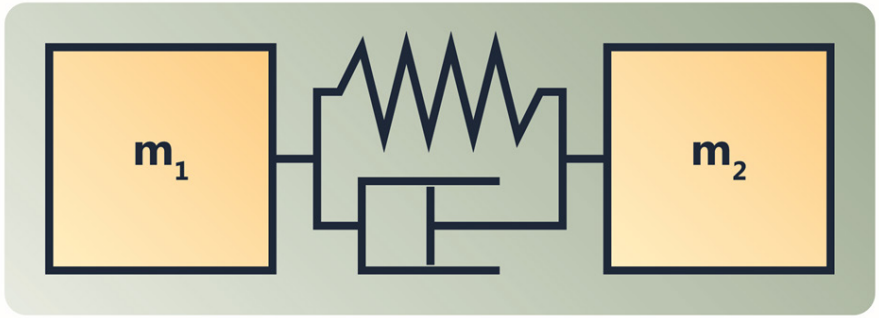
Human Communication Interface

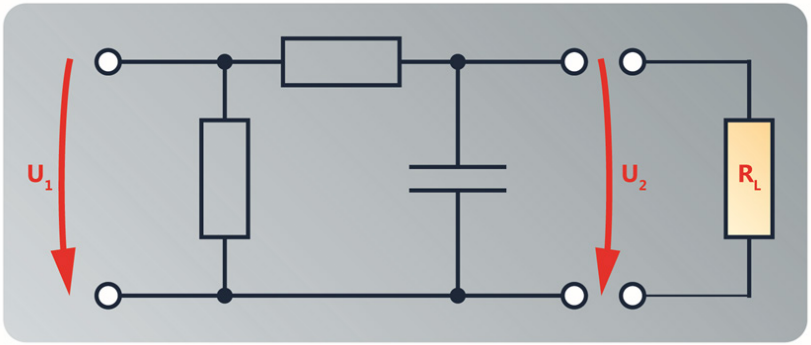


- Information flow is only one aspect of human communication
- The SoS interface design needs to consider all aspects of human communication

Physical Interfaces

- Physical laws define mutual dependencies between input and output
- Unidirectional motion or flow of energy can be approximated only





The Intricacies of System Interface Engineering

- Information flow has to consider human communication
  - When to transmit which information?
  - How to disseminate information to the human receiver?
- Physical implementations of information flows may be implemented on rather lower system levels
  - Abstraction layers help to reduce the direct impact of physical implementations (OSI network layers)
  - Compatibility of system elements may be still an issue
  - Interface development may become cumbersome in case of compatibility issues

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Conclusions

- System-of-Systems considered in the context of organisational workshare between different legal entities
- Changes of procurement policies within NATO and its member countries in the 1990s led to the emergence of system-of-systems considerations
- Aside traditional interoperability issues, NATO system interoperability today is dominated by information technology
- System interface engineering has deep impact on lower level systems
  - The second lecture tomorrow will dive deeper into system interface engineering when the overall systems engineering value stream is presented

Thank You

for your attention

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