The challenge of increasing heterogeneity in Systems of Systems for architecting

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Abstract

The transition from capabilities provided by traditional physical systems to todays capabilities provided by heterogeneous systems of systems complicates architecting. In this paper, we look at trends in this ongoing transition, especially into the degree of heterogeneity of technologies and the context. We observe in an increase in virtual intangible technologies from the cyber domain, and an increase in human and organization aspects. Main question is how the heterogeneity of concerns, needs, considerations, and technologies impacts architecting and the role of architects.

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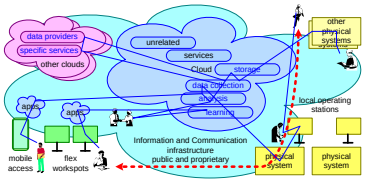
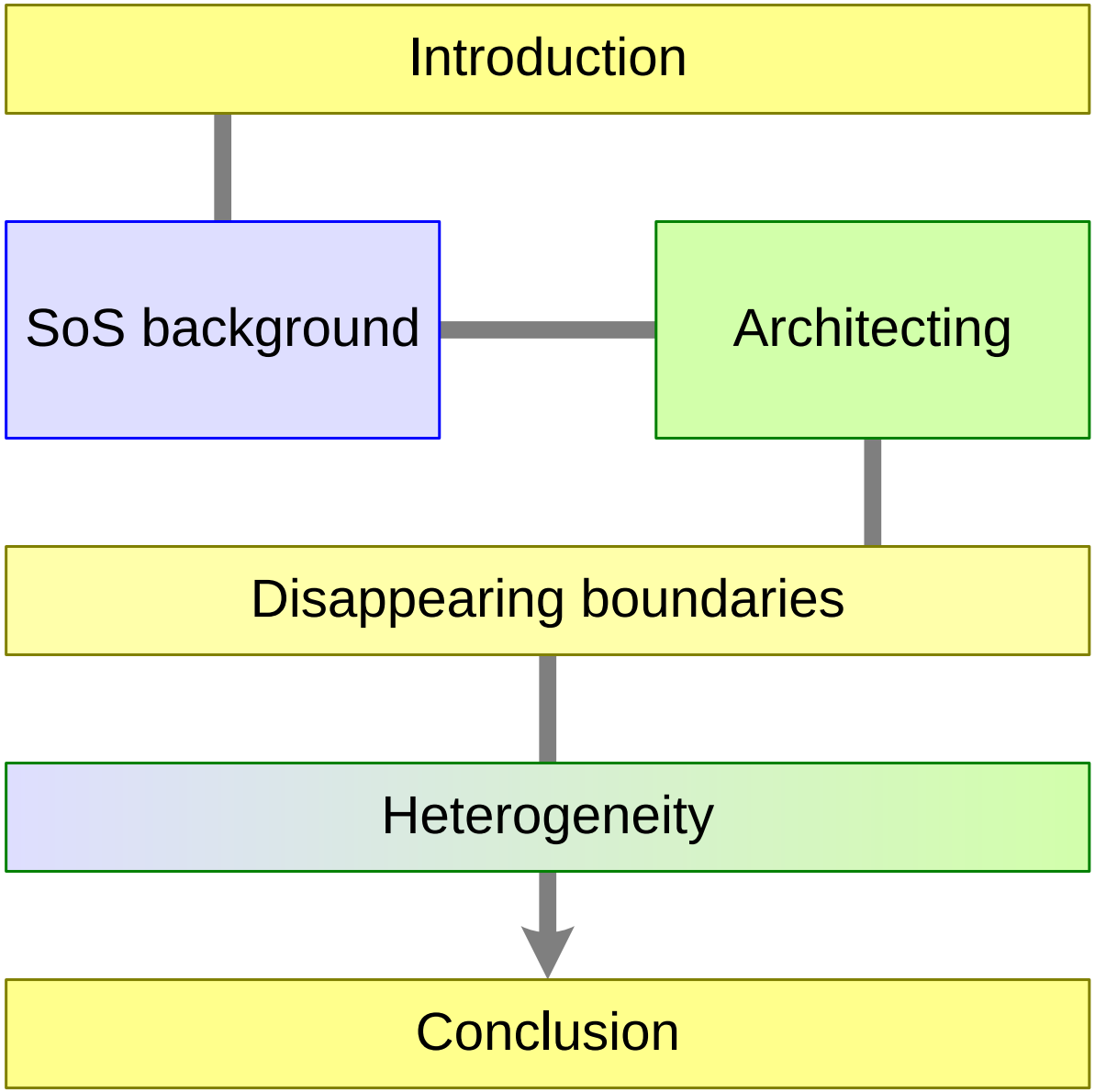


Figure Of Contents™



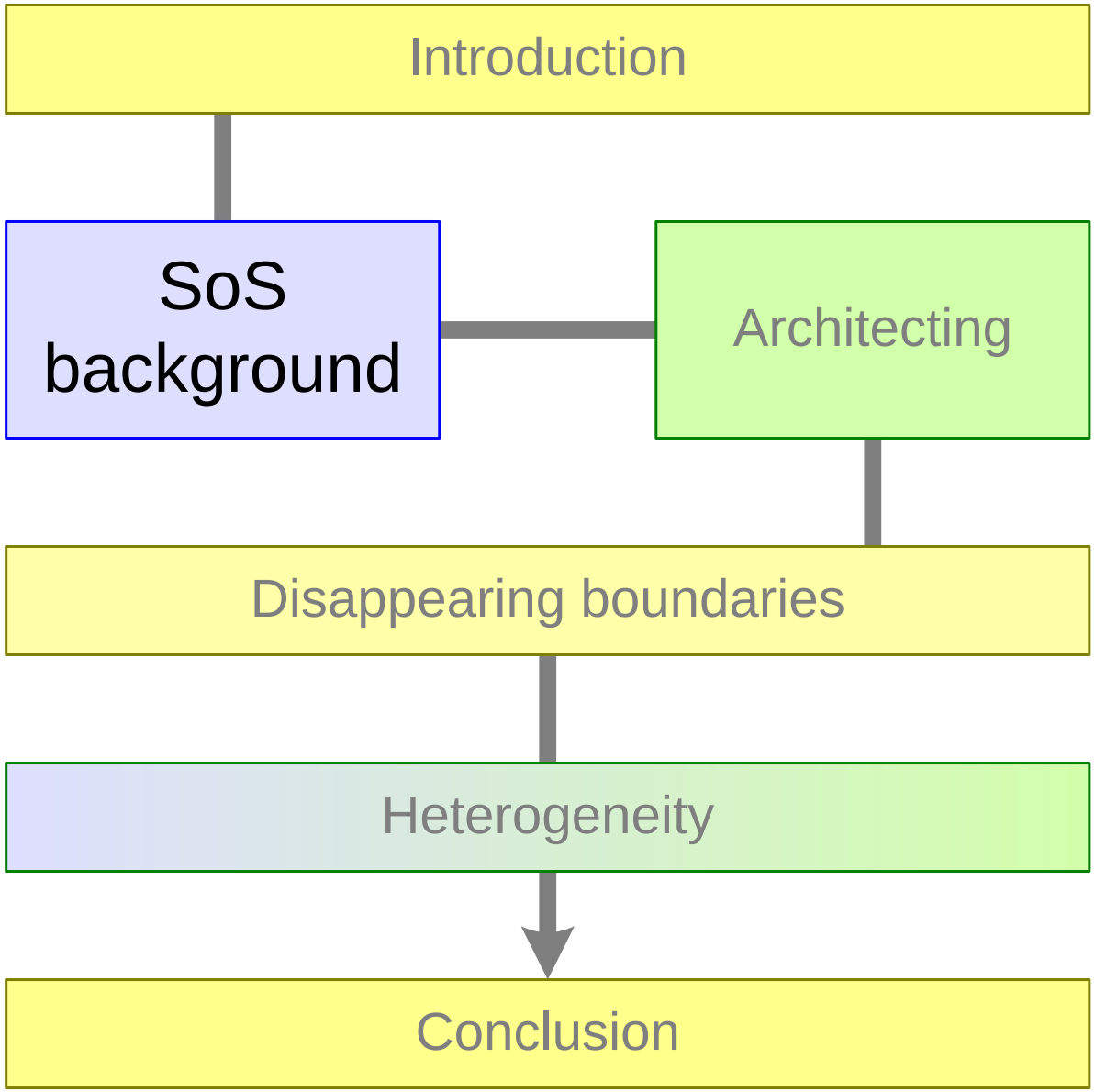
Observations from teaching in various domains

- Health care
- Defense
- Maritime
- Oil and gas
- Manufacturing
- OEM equipment for imaging, printing, machining
- Automotive

Trends across domains

- Growth of data/information collection
- High expectations from harvesting useful data across systems to improve performance and functionality
- Infrastructure platforms using cloud technology, factoring out common digital functionality
- Ubiquitous use of commodity devices as smart phones, tablets, and laptops
- Focus on trustworthiness and affordability
- More automation and considering autonomy
- Societal pressure for privacy and responsible behavior

SoS Background



Keywords from various SoS models in literature

Boardman and Sauser	Maier	DeLaurentis	Dahmann and Baldwin
Autonomy	Operational independence	Type	Directed
Belonging	Managerial independence	Control (or autonomy)	Acknowledged
Connectivity	Geographic separation	Connectivity	Collaborative
Diversity	Emergent behavior		Virtual
Emergence	Evolutionary development		

Types of Systems of Systems

Directed - The SoS is centrally managed

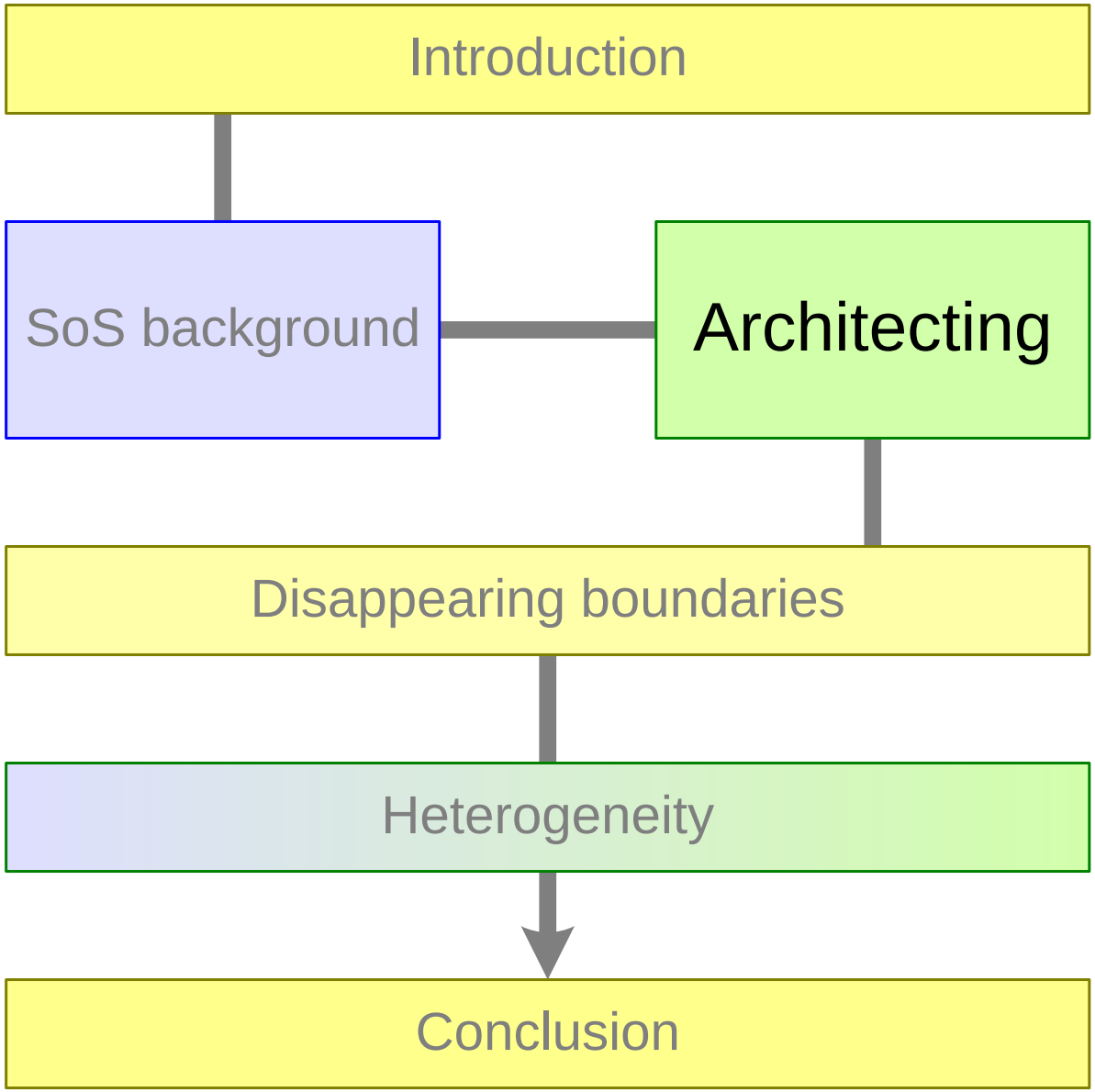
Acknowledged - The SoS has recognized objectives, and active cooperation between SoS and constituent systems

Collaborative - The constituent systems and stakeholders cooperate

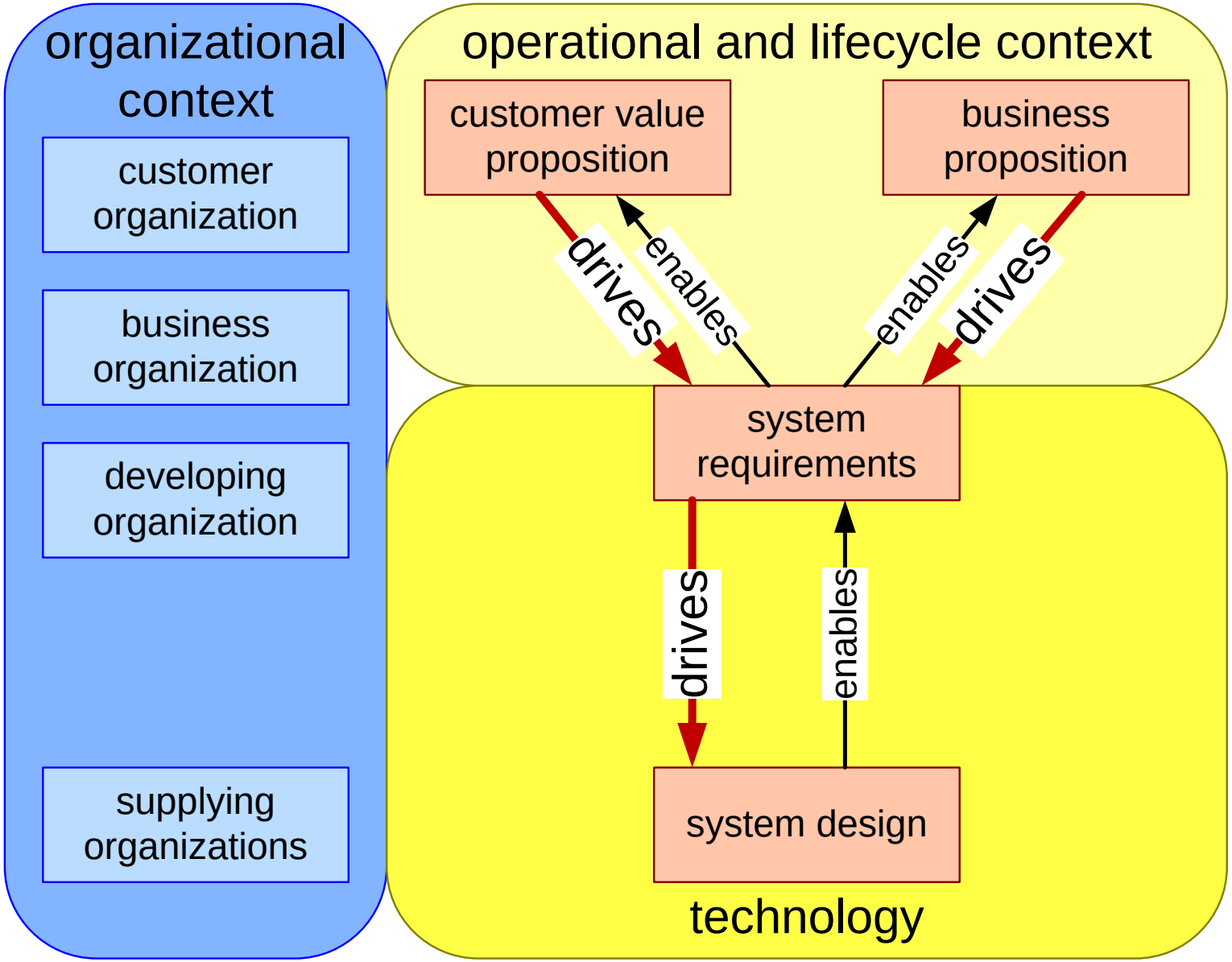
Virtual - The SoS nature more or less emerge from the constituent systems

J. Dahmann and K. Baldwin. 2008. "Understanding the Current State of US Defense Systems of Systems and the Implications for Systems Engineering." IEEE Systems Conference 2008 in Montreal, 2008

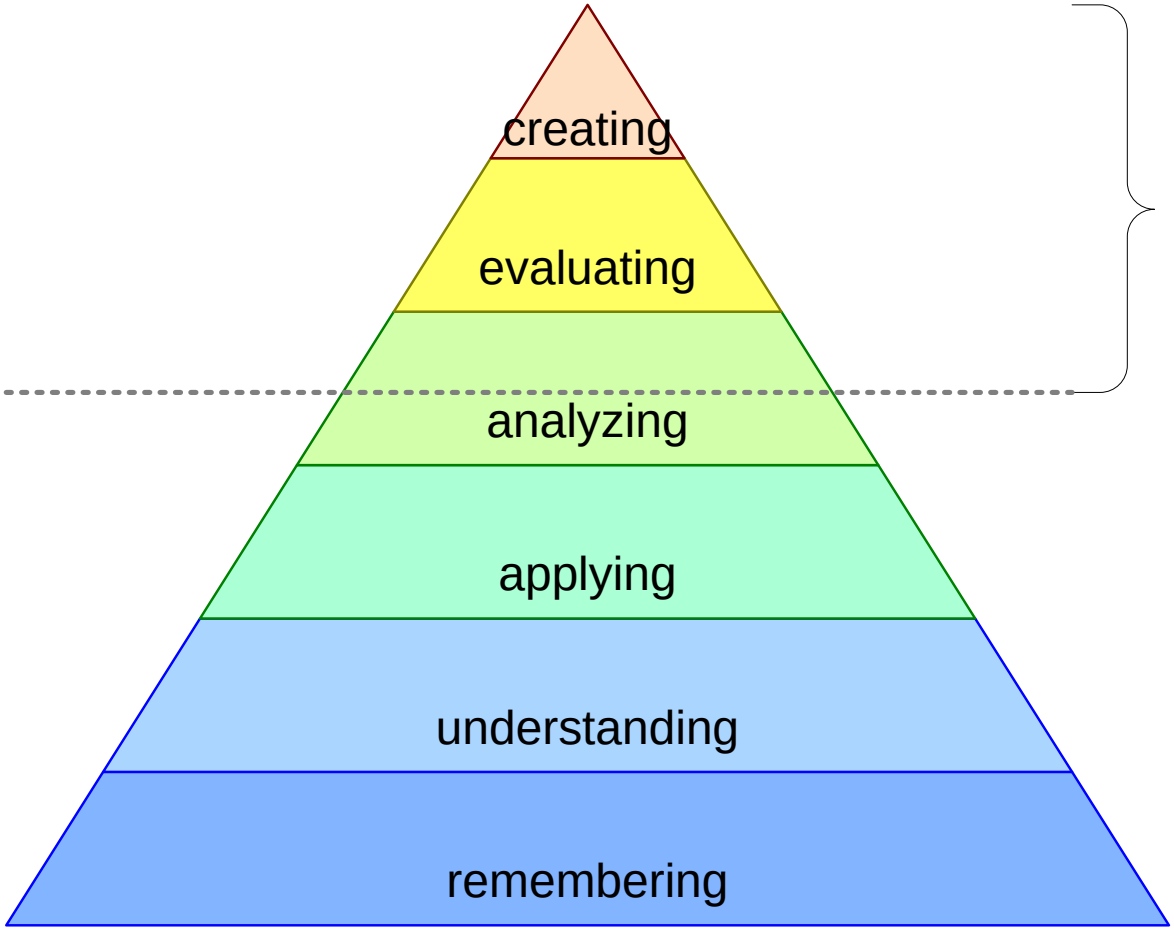
Architecting



The architecting playing field



Thinking skills in Blooms revised taxonomy

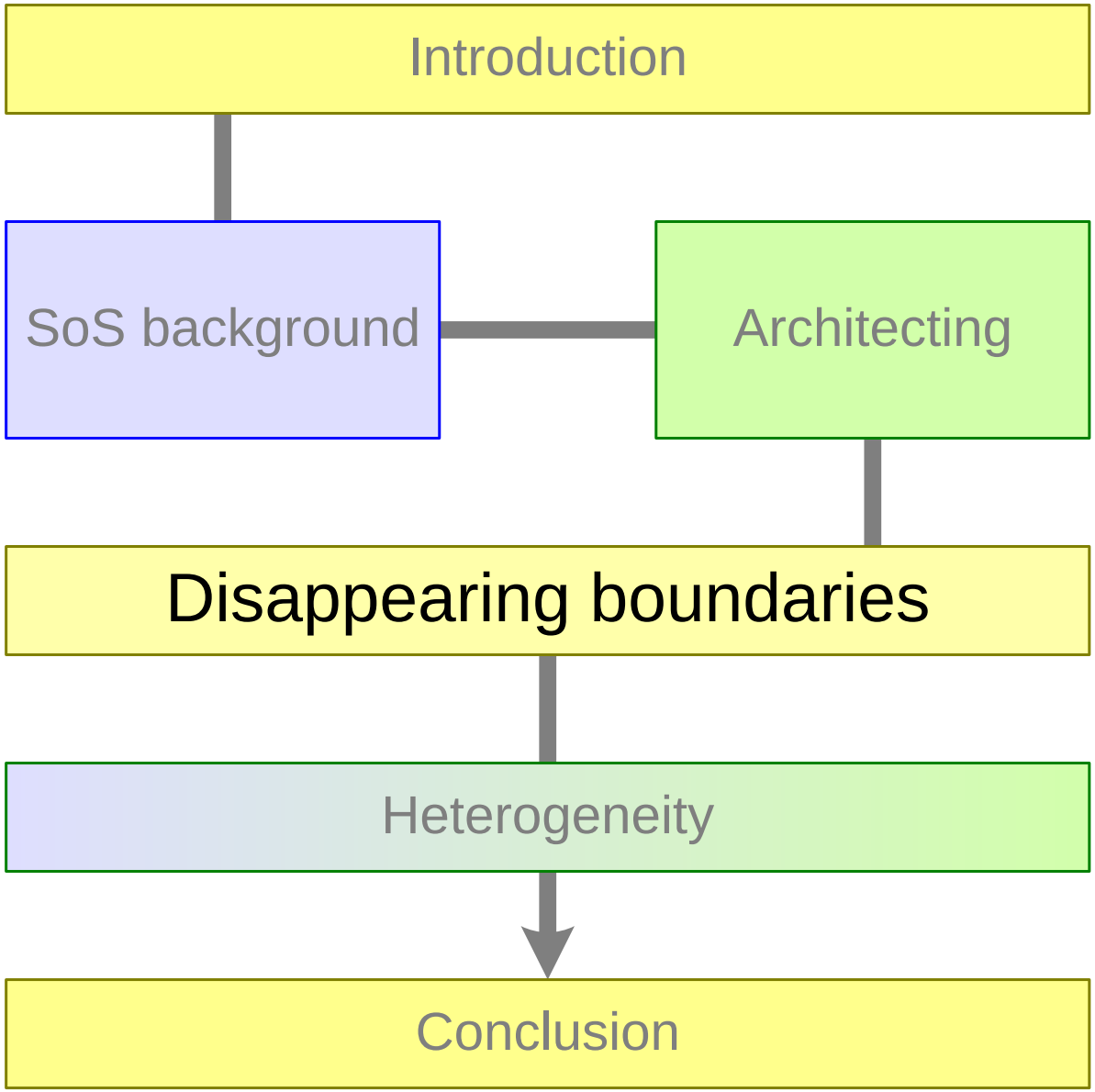


Higher Order Thinking Skills
more difficult to teach
more valuable
takes time to develop

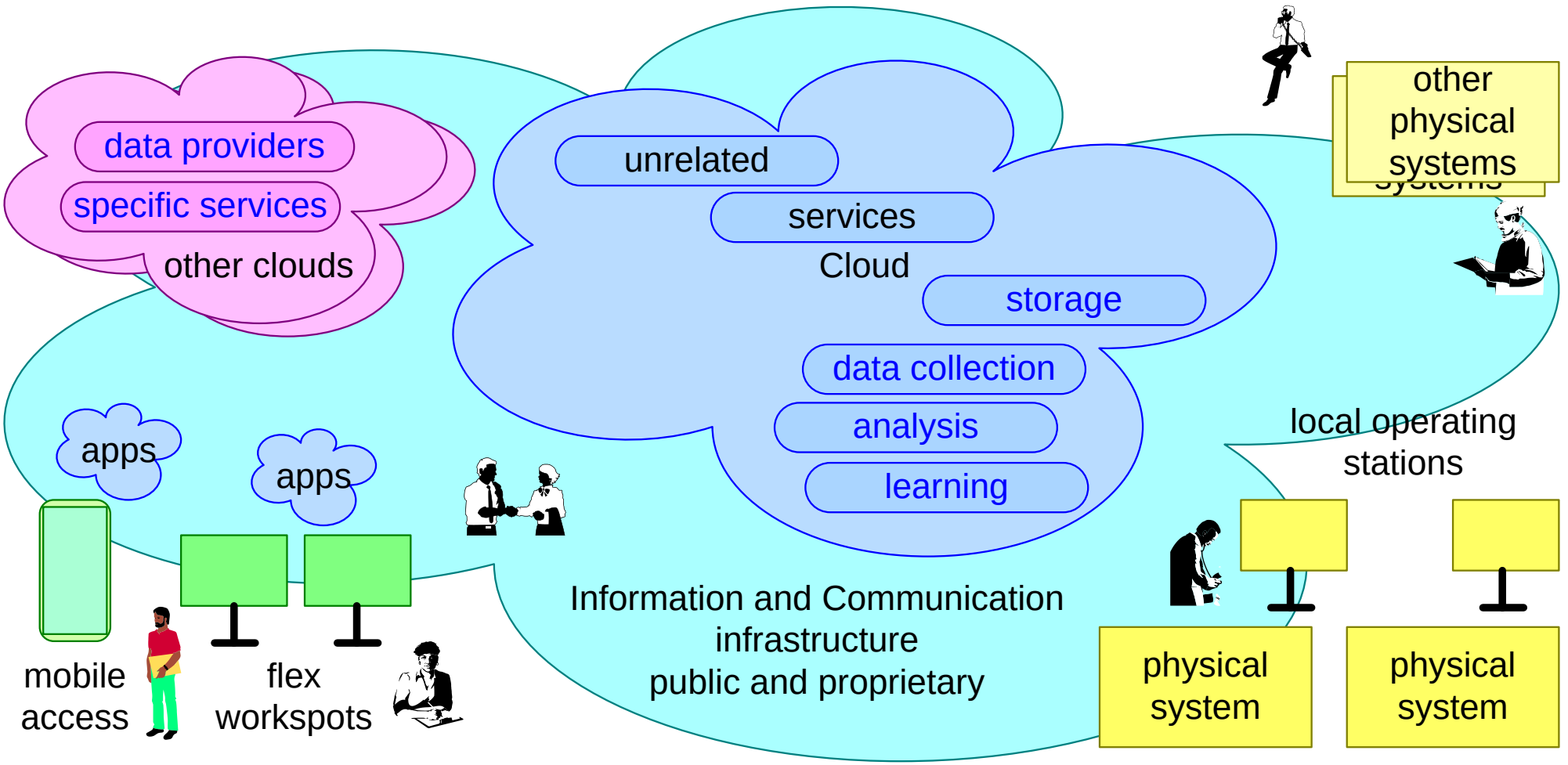
must be mastered before,
however when missing
can be acquired fast

Lower Order Thinking Skills
people can acquire them fast

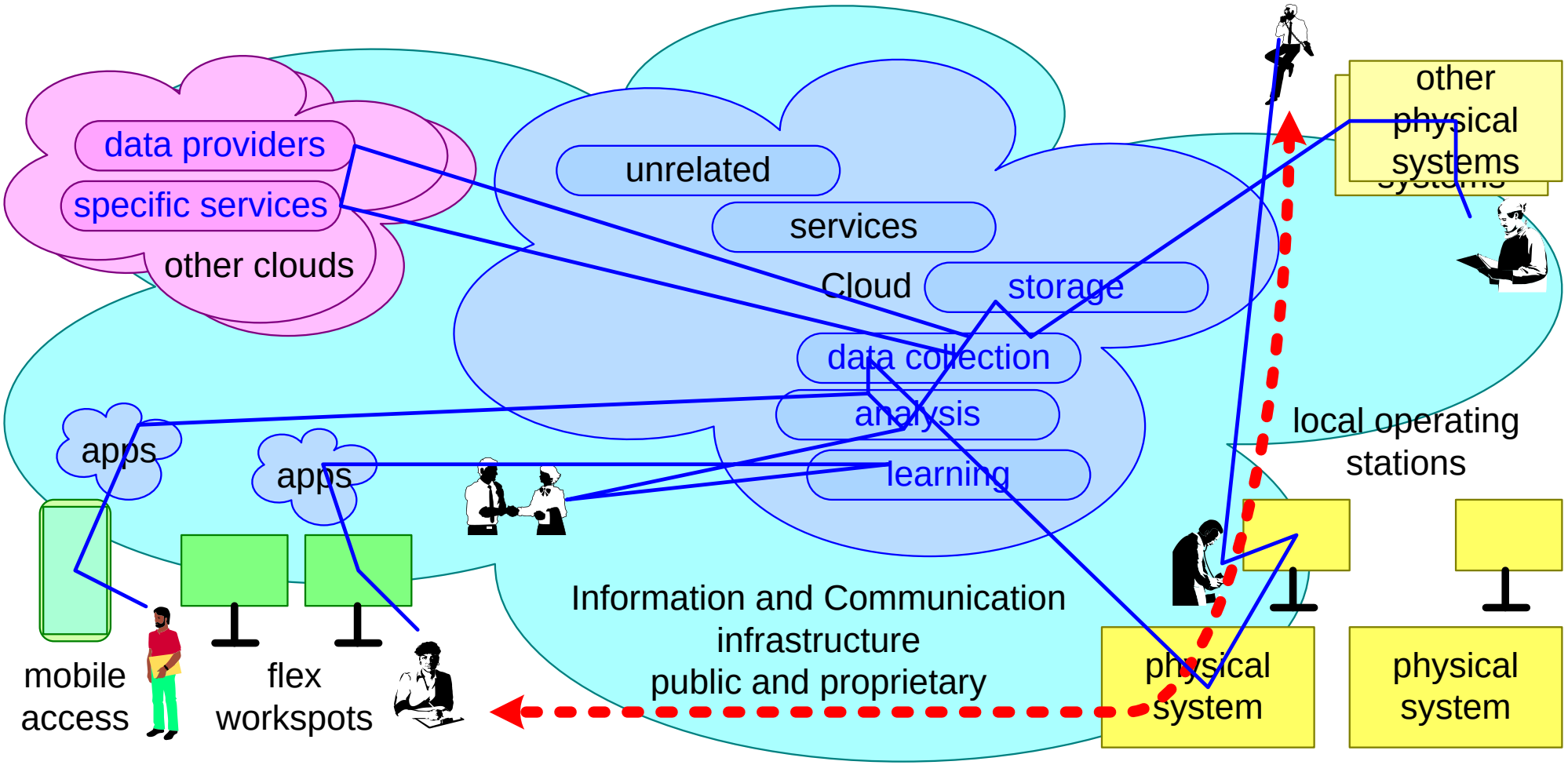
Disappearing Boundaries



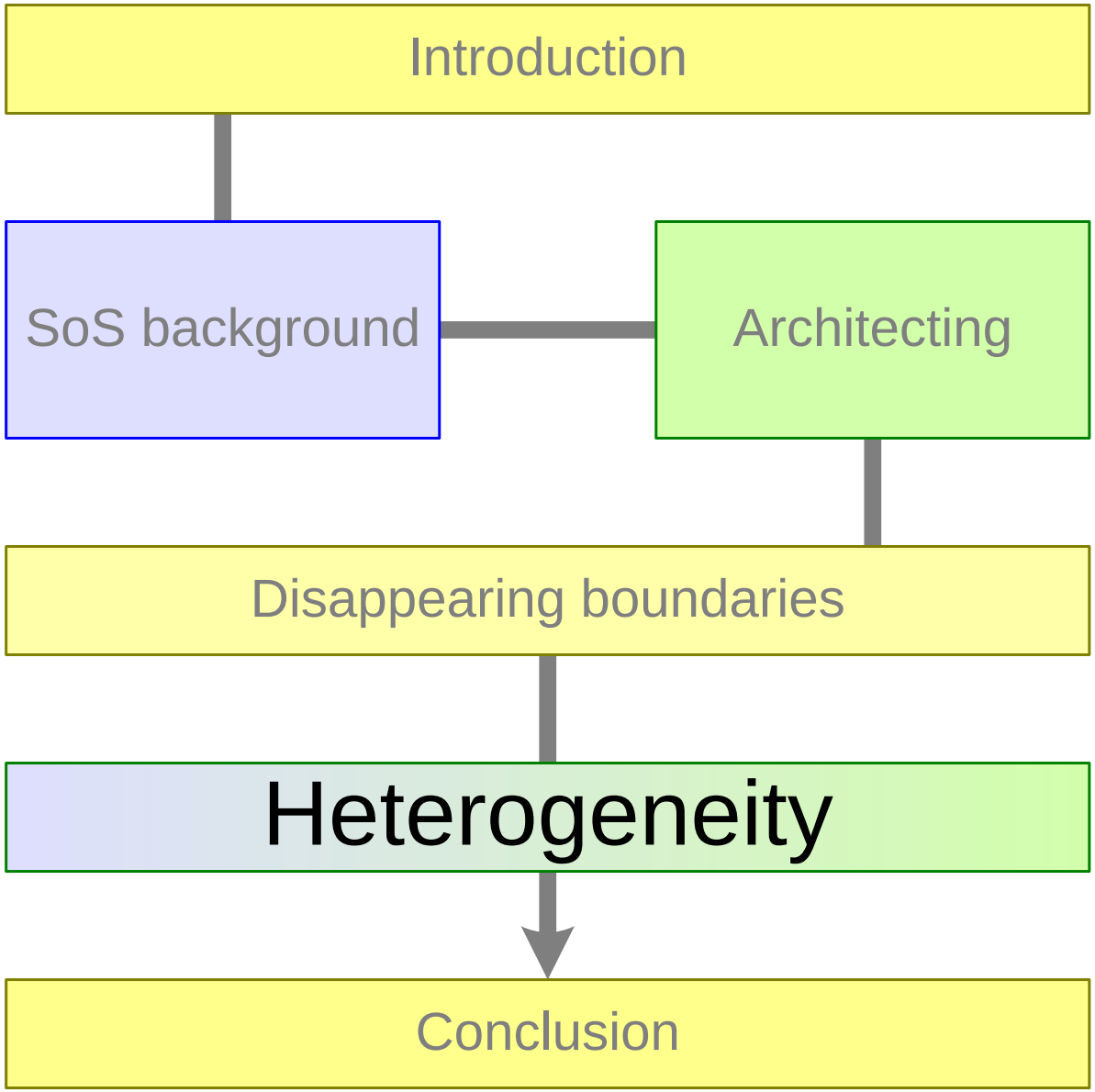
Where are the System Boundaries?



End-to-End Function



Heterogeneity



New Virtual Technologies

traditional (physical) technologies

- chemical engineering
- mechanical engineering
- electrical engineering
- optical engineering
- civil engineering
- operations research
- physics

upcoming technologies

- Internet of Things
- miniaturized and commoditized sensors
- ubiquitous networking, storage and processing resources
- Artificial Intelligence, ((deep) learning, data mining, data analytics)
- block chain
- microservices
- clouds

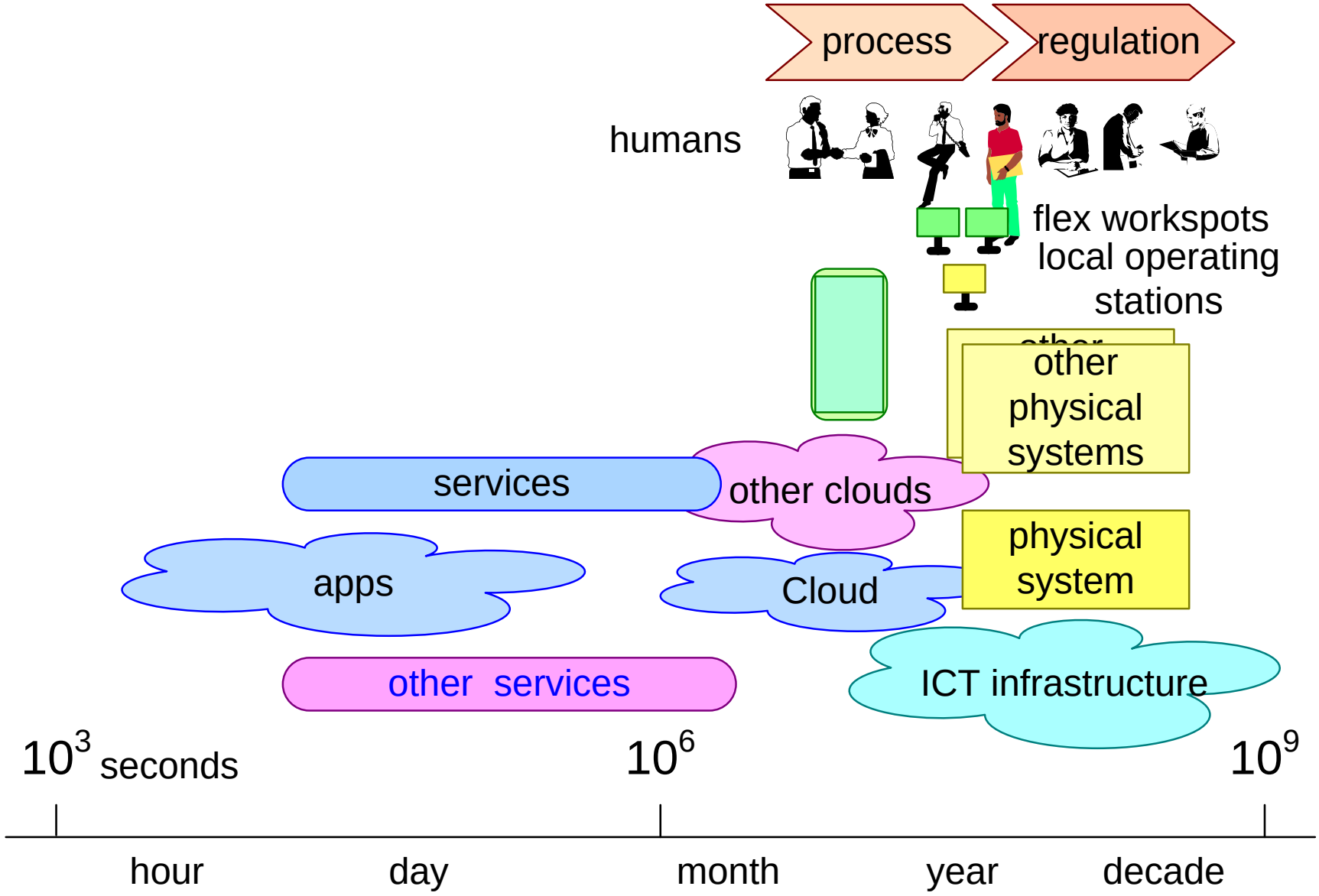
Non-technical heterogeneity

non-technical considerations

- economical
- ecological
- legal
- social,
- political
- psychological
- criminal

human behavior:
emotions, social pressure, political gains
may trigger unexpected behavior.

Varying Dynamics



tension between control and emergence

safety, security, etc. requiring anaylsis and control

versus

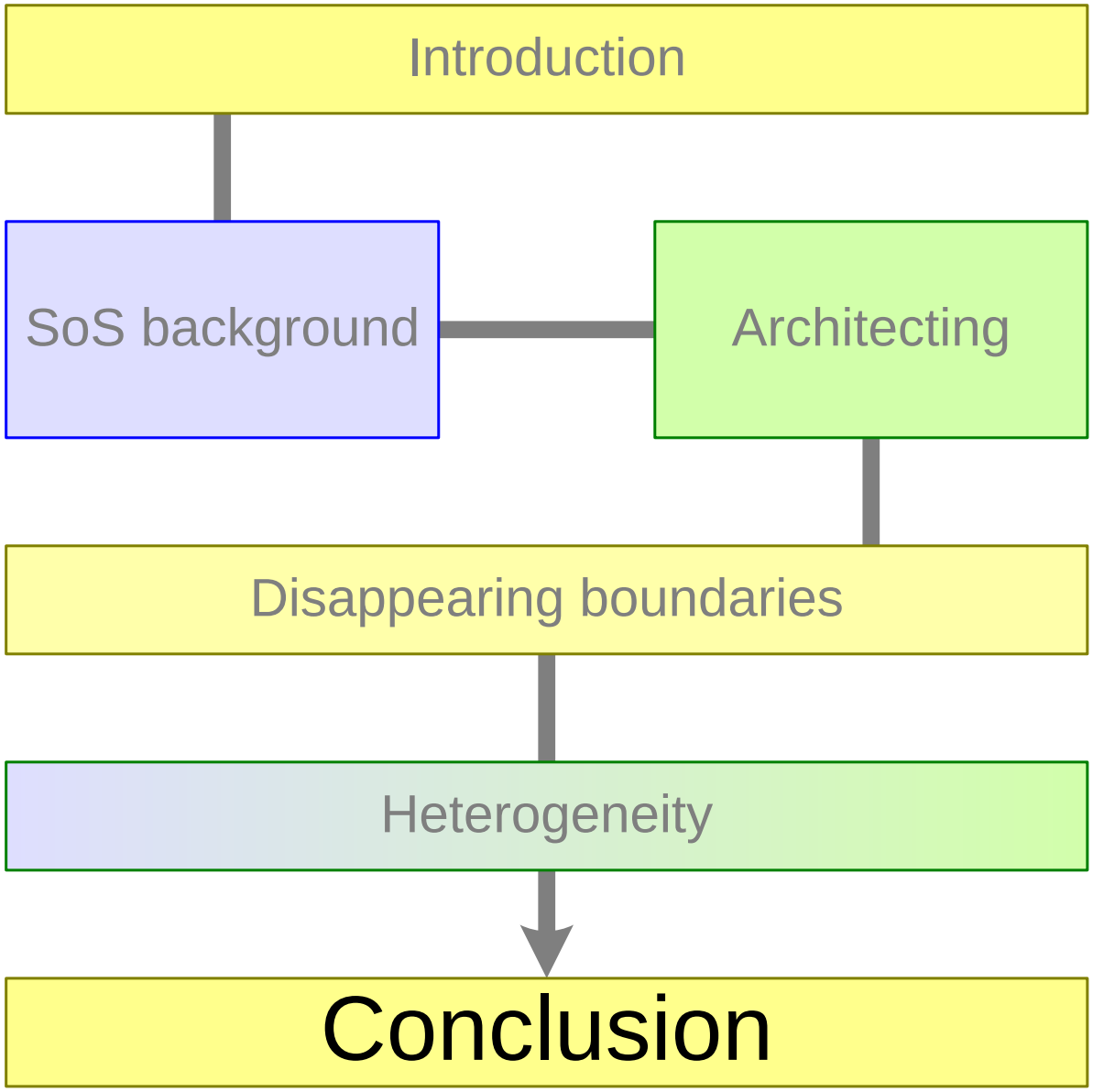
emerging and changing behavior, e.g. due to Artificial Intelligence

clear ownership

versus

dynamic allocation and distribution of services

Conclusion


Introduction
SoS background
Architecting
Disappearing boundaries
Heterogeneity
Conclusion

Summary

- Systems of Systems Integration **continues in the field** during operation
- **Ownership** and **responsibility** for end-to-end performance is **ill-defined**
- **Your system** may be **blamed** for problems with a **root cause elsewhere**
- End-to-end performance depends on a mix of
  - traditional **technical** systems
  - **modern technologies** like learning
  - **humans** in their organizational and societal context (psychological, social, political, economical, legal, etc.)
  - the **physical** context (location, climate, etc.) and laws of physics

Links

The challenge of increasing heterogeneity in Systems of Systems for architecting https://gaudisite.nl/SoSE2018_Muller_heterogeneity.pdf IEEE SOSE 2018 in Paris, France, copyright IEEE "http://ieeexplore.ieee.org/xpl/mostRecentIssue.jsp?punumber=7533679"