A systems view of Systems Engineering - the field in its intellectual context

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Outline – message: *Be aware of similar toolboxes to SE*

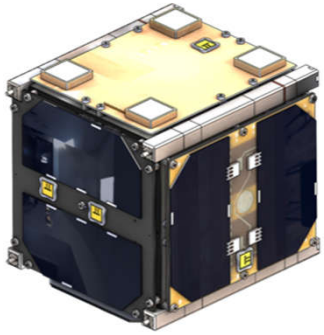
Part 1 – Introduction: Systems Engineering at EPFL

- EPFL Space Center research

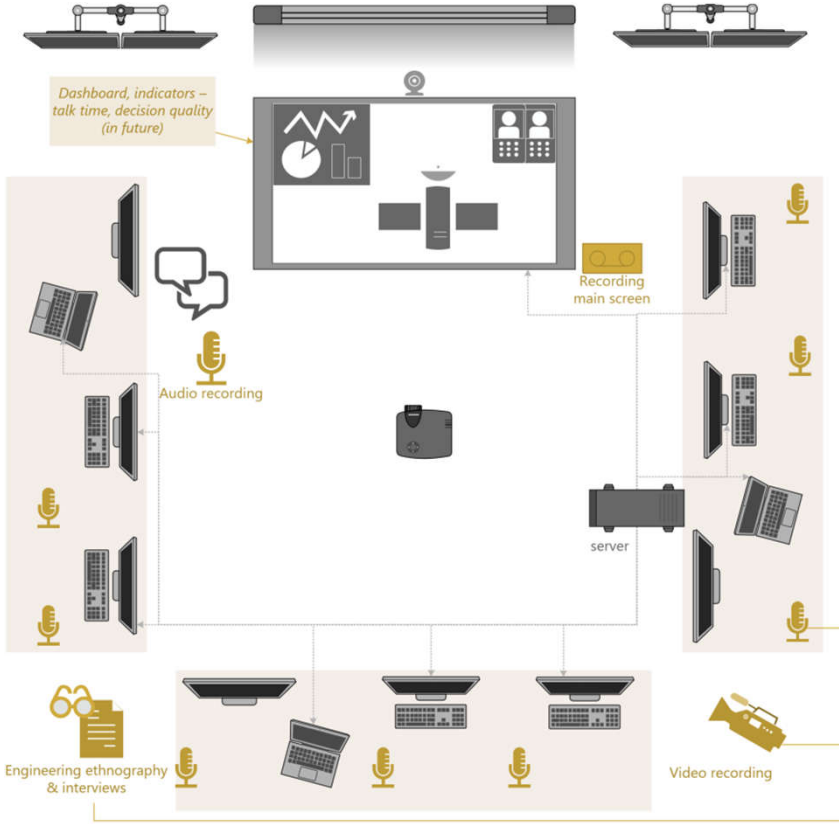
Part 2 – Systems-related fields: history, context, *raison d'être*

- Fields sharing the goal of SE:
  - Engineering Design
  - QFD
  - PLM
  - Agile method & Concurrent Engineering
- Guide to toolboxes

SE activities at EPFL



- **One of first Concurrent Design Facilities at a University**
  - **Now being made Next-Generation**
- Minor in Systems Engineering
  - ~25 Master's students/year
- ~2-4 professors related to discipline
  - famous MIT Prof. Olivier de Weck associated
- EPFL's Space Center is a Systems home
  - Switzerland's first satellite (SwissCube)
  - EPFL Rocket Team



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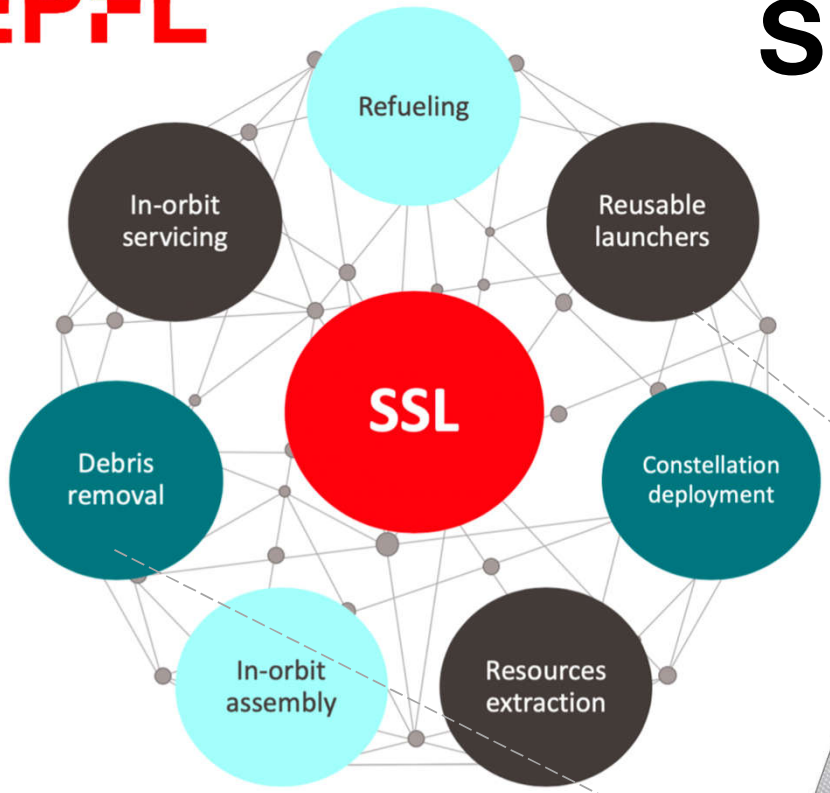
Sustainable Space Logistics

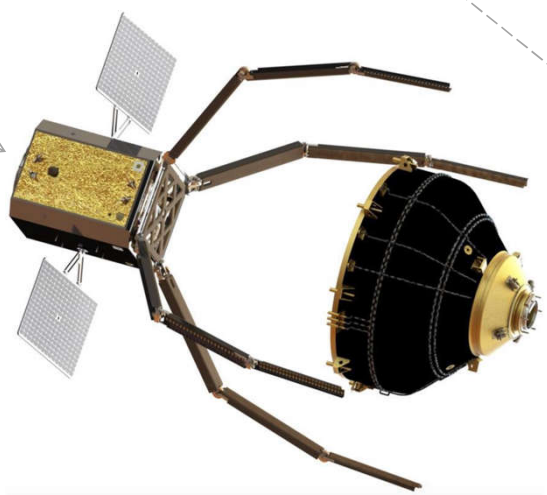


Research initiative with **a systems and SoS view of space,** combining 2 concepts linked to holism & systems

Sustainable
Ideal, new thinking; an ESA & European priority

+

Logistics
Practical, holistic; shift space system design drivers from performance to cost & schedule



Awarded ESA mission: ClearSpace-1 active debris removal (to spin-off *ClearSpace* – **86M€ mission**)

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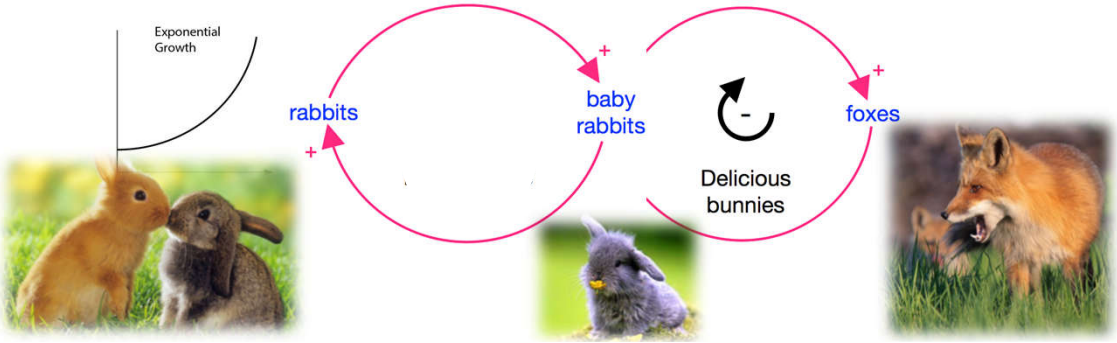
Systems fields: history

- 40s & earlier: Industrial engineering
  - Engineering challenges move outside the factory
  - Operations Research & WWII: problem formulation
  - Systems analysis: OR in peacetime
- **US** space race, Cold War, computing:
  - New “messy, complex problems”
- NASA – interdisciplinary trade-offs, complexity
- Control Theory
  - Cybernetics
- 50s: General Systems Theory
- Early computer simulation
- Milestone: *The Limits to Growth*
- Systems science – biology, ecology, Earth science

The Club of Rome, 1972 Meadows report



Systems fields: context

To (do other stuff than make products)

By thinking holistically, about interconnections…

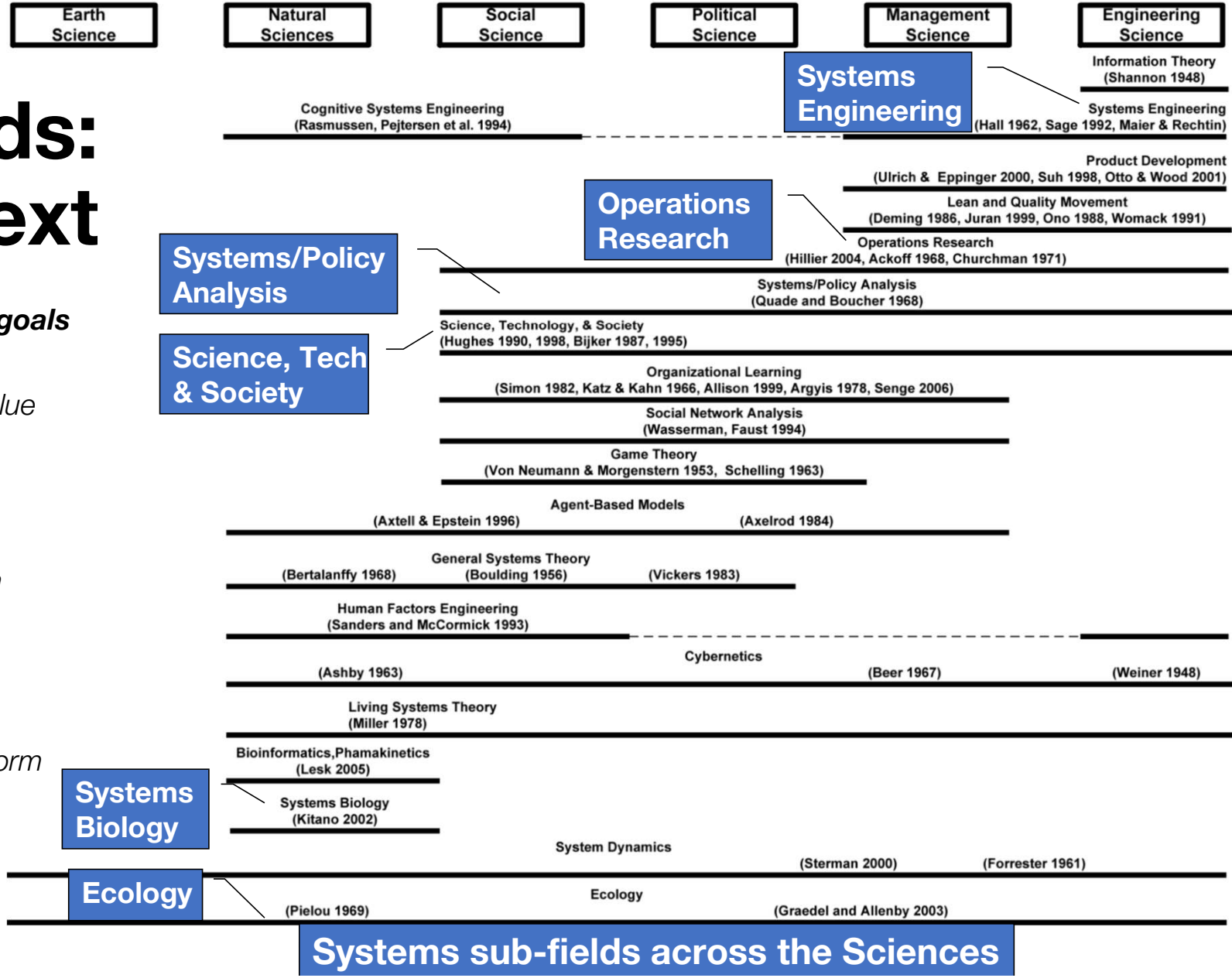
Using Systems Thinking

Hierarchy of goals

To*: goal, value*

By*: function*

Using*: form*



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Bartolomei 2007 PhD thesis

Systems Engineering: *why?*

- What is Systems Engineering's *function*?

  Marcus Aurelius, Roman emperor
  "For any particular thing, ask:
  ***What is it** in itself?*
  *What is its **nature**?"*

- "Systems" answers "how", more than "what/why"
- We tell engineers: "*think about your domain's connections to others, about the big picture*"
  - But other paradigms share the g

- **Eat our own dog food!**

To enable the realization of successful systems

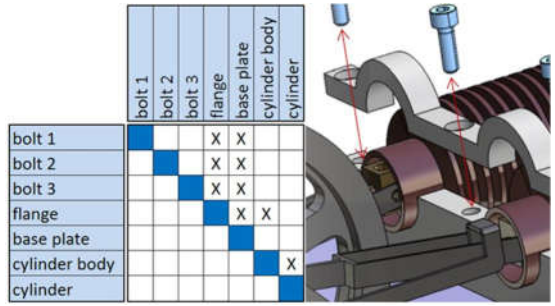
By considering them in a holistic, interdisciplinary way up-front

Also here!

There are alternatives here!

Using Systems Thinking and Engineering

Engineering Design



- Origins in Mechanical Engineering
  - Consumer products, automotive
  - **Europe** (e.g. Germany, Pahl & Beitz 1977)
- Focus on product development processes
- Design Theory, Design Research, Design Thinking
  - Understand *design as a human activity*
- Design Society is very active in research
  - but no “INCOSE equivalent”?
- E.g. the field “owns” Design Structure Matrices!
  - N^2 matrices: show connections between functions, components, etc.

To enable the realization of successful systems

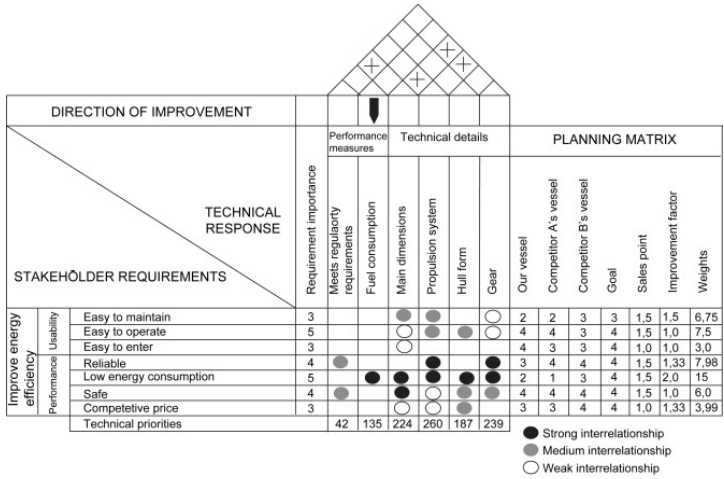
By considering them in a holistic, interdisciplinary way up-front

Using Design Thinking and Engineering

David Kelley, founder of IDEO and Stanford’s d.school

QFD

(*Quality Function Deployment*)

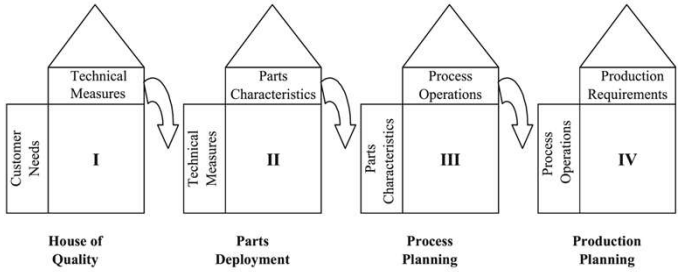


- Origins in Quality movement, manufacturing
  - Product development using “Total Quality Control”
  - Manufacturing-based, “imitation economy” shifts to original design
  - Links to Value Engineering, TQM, Six Sigma
- **Japan** in 1960s
  - Akao-sensei at e.g. Kobe Shipyards, then Toyota
  - Fame: “Japan scare”, bubble years in 1980s
  - Went to US & Europe in 80s, then back to Japan
- ISO standard, wide industry use
  - Originally 30+ matrices flow-down

To enable the realization of successful systems

By considering them in a holistic, interdisciplinary way up-front

Using “deployment” of customer needs clearly down via design to production



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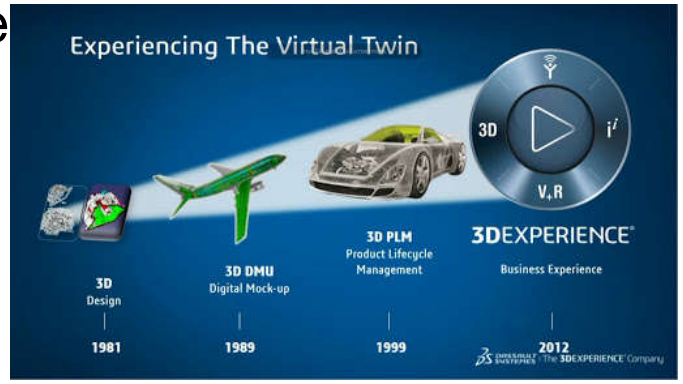
PLM

(Product Lifecycle Management)

- Origins in **US**, 1980s: AMC (Jeep), Rockwell
  - Issue: design support systems – connect to exchange & reuse info
- Idea: central database of interconnected engineering models
  - Modern outgrowth: “digital twin”
- Connecting CAD and other models
  - Closer to detail design
  - Quite successful now (tech winds), “going upstream”
- More industry-driven and tool-drive
  - Analogous to CRM, SCM, ERP
  - Less academia… or theory
- Claim: “bottoms-up” vs. SE “top-down”



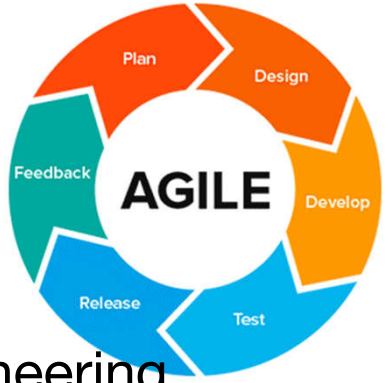
To enable the realization of successful systems

By considering them in a holistic, interdisciplinary way ***throughout***

Using a product information system backbone and single source of truth

Agile Method & Concurrent Engineering

- **Concurrent Engineering**
- Early 1990s, associated to **Toyota** best practices, NASA
- Concern: away from “over-the-wall” engineering, accelerate early design
- Collocated team simultaneously, rapidly designs system, transparently
- Often has
  - Knowled



- **Agile development**
  - Close to Scrum, Lean etc.
- Origins in **software** engineering
  - early 2000s
  - Rapid prototyping, start-ups
- Key concerns: difficulty in planning, requirements changes, feedback
  - Also enabled by nature of software
- Very popular
  - Attempts at extending, combining
  - Increasing software everywhere…

Guide to toolboxes

- Fields: “schools of thought of product development”
  - or “*how to make stuff better*”

Field	Key Focus	Approach	Resources
Systems Engineering	Complexity, holism, system goal, connections, lifecycle	V-model, key role (SE), focus on requirements flow-down, V&V	Blanchard & Fabrycky, NASA & INCOSE handbooks

Conclusion: call for action

- **Use other toolboxes!**
- SE is not the answer to everything – don't be too silo'd!
  - Why don't we collaborate more? With other fields, approaches!
- "Why isn't Systems Engineering more popular?"
  - We aren't looking with the right words!

- Idea: Systems Engineering as a "school of thought"
  - for goal "*how to make things better*" let's focus on this **goal**, not the tool
  - There are other schools. Each has strengths & weaknesses
- NOT trying to:
  - Muddy the waters
  - Say "SE is bad" actually opposite, saying "*our concerns are widely shared*"

Annotated references: some attempts to bridge disciplines

- Hillary Sillitto (2014), INCOSE IS, "*Integrating Systems Science, Systems Thinking, and Systems Engineering - understanding the differences and exploiting the synergies*"
- Zane Scott's (Vitech) (2020, updated) INCOSE talk: "*Family of Systems Disciplines*" https://www.youtube.com/watch?v=Yr32LUThL2o
- Jason Bartolomei's PhD thesis introduction (2007, MIT)
- MIT's *Engineering Systems* concept, division, & book series (from 1998)
  - SE+ technology & policy + system & decision analysis, Operations Research + Engineering Management & Innovation + Manufacturing, Product Development, Industrial Engineering
  - SDM & IDM twin master's programs ("systems" & "design")
- M. Mangieri (post-1998), *The Role of QFD in Systems Engineering*, (and many others) http://mjmangieri.tripod.com/SE/mswe603.htm
- Maier & Rechtin (from 1991), *The Art of System Architecting* (e.g. QFD+SE, a bit

THANK YOU!

- Questions, comments?
- This is just a rough starting point!
- Please get in touch to discuss, or to learn more about Next-Generation Concurrent Engineering!