

# Towards a framework of research methodology choices in Systems Engineering

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# Systems Engineering Research Choices

- *What* to study ... (substantive)
  - Many choices
  - Requirements are usually fairly clear
- *How* to study ... (methodological)
  - Many choices
  - Requirements are usually unclear
  - Many of the options are probably unknown
  - Risks, best practices, challenges are probably also unknown.

# SE Research Methodology Questions

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1. Why is methodology important in systems engineering?
2. What is the difference between methodology and method?
3. What methodological choices exist and which choices are better than others?
4. How do you connect theory, methodology and domain?

# SE Research: Examples

- Analysing SE performance, based on established processes and heuristics (and potentially theory from other disciplines) in order to propose improvements
- Analysing SE performance, based on established processes and heuristics (and potentially theory from other disciplines) in order to explain certain phenomena
- Applying SE to new domains in order to develop theories about how its application differs

# What SE Research isn't ...

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- Understanding the factors affecting life expectancy of systems engineers
- Adherence to a systems engineering process in the development of a new vehicle
- Modelling and demonstration of the reliability of a component

# Motivation

- A serious, scholarly discipline has to show that...  
“...within the subject there is a cycle of interaction between the formulation of theory relevant to serious problems or concerns, and the testing of that theory by the application of methodology appropriate to the subject matter... It will lead to ideas from which we can formulate two kinds of theory, **substantive** theories about the subject matter ... and **methodological** theories concerning how to go about investigating the subject matter.”

Checkland [1981]

# Differentiating between Methodology and Method

- Lack of discipline in terminology is a problem in systems engineering research
- Many researchers use the terms methodology and method interchangeably
- This makes it difficult to
  - (1) compare research results across studies,
  - (2) communicate results to sponsors, and
  - (3) share results with other disciplines.

# Differentiating between Methodology and Method

“The distinction between methodology and methods is crucial here. Methodology is a **higher order term** that refers to the **logical principles** that must govern the use of methods in order that the philosophy/theory embraced by the approach is properly respected and appropriately put into practice. **Methodology is not detachable from the philosophy/theory of the particular systems approach**, or, therefore, from the approach itself. Methods, however, concerned as they are with achieving more specific procedural outcomes, are detachable and can be used in the service of other systems approaches with varying degrees of success and failure”.

Jackson [2003]



# SE Research Methodologies: Common Traditions

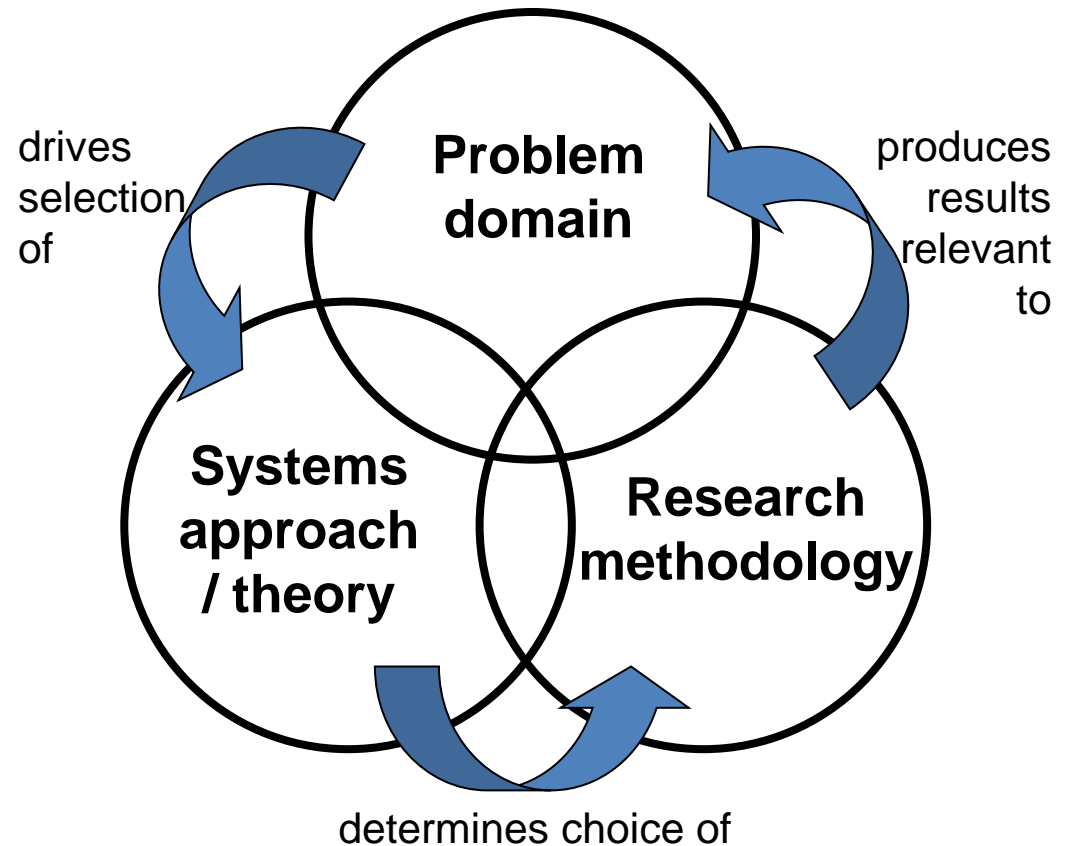
- **Positivist tradition**
  - Define the theory first and then validate.
  - Most researchers overlook the possible limitations of the approach, e.g. the rigidity in which hypothesis testing is done.
- **Method based tradition**
  - The “copycat” approach: replicating someone else’s method.
  - The dangers are in the transferability of **methodology** from one context to another, and the assumption that the original methodology was correct.
- **Directed tradition**
  - “My supervisor told me...” approach.
  - Typically based on:
    - personal specialty,
    - the context in which the research sponsor is supporting the work,
    - the availability and form of the data,
    - the intellectual traditions of the academic department, university or country.

# Breaking with Tradition

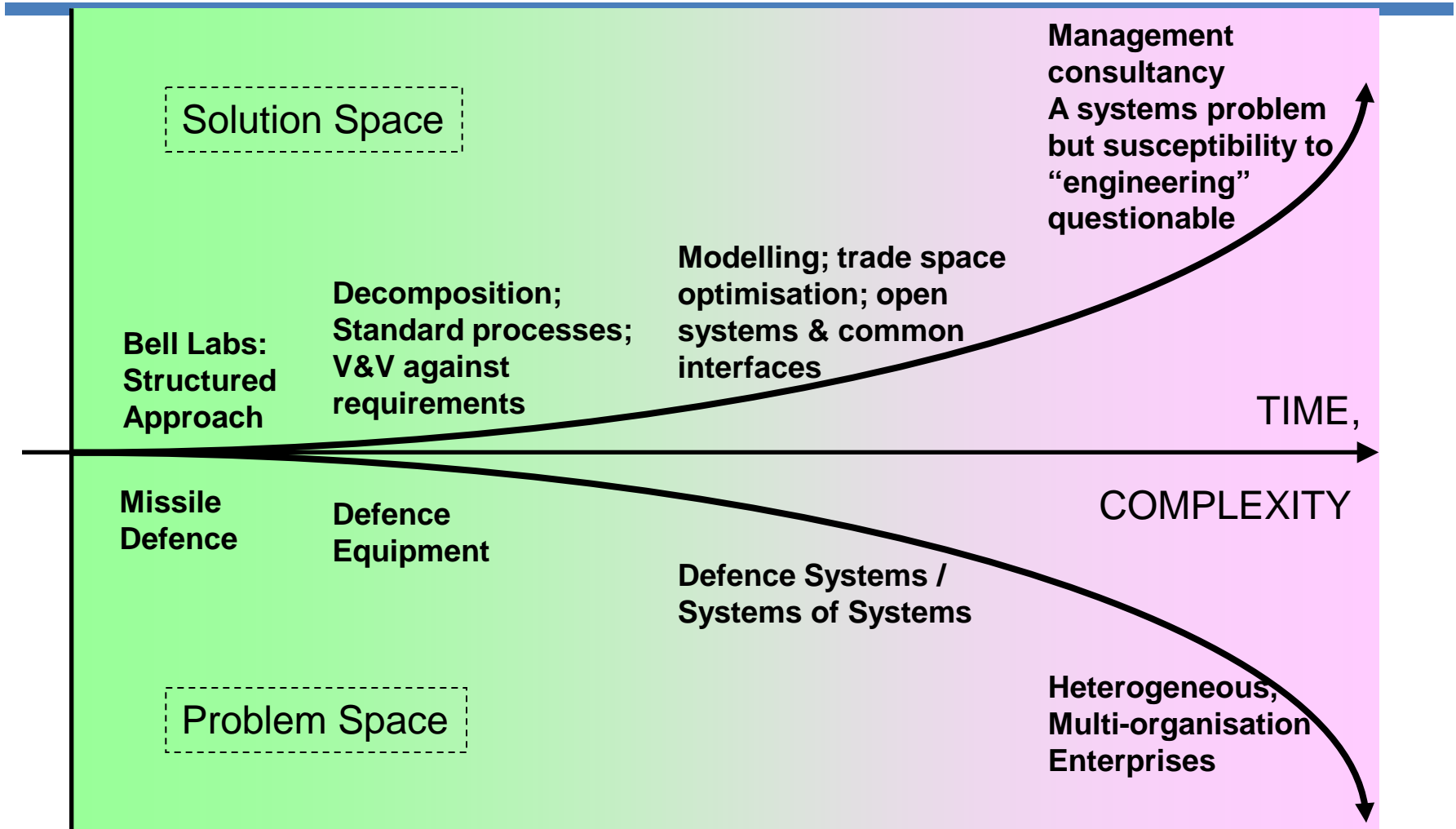
- Researchers need to make their own methodological decisions based on the context of their study and the underlying philosophy and theory that motivates it.
  - Recognising the theoretical assumptions implicit in:
    - The problem context
    - The research question
  - Refining the research question to align with the theoretical assumptions
- Using the higher-order concept of methodology to translate the philosophy/theory into practical application, i.e. to identify the method (the different models, tools and techniques) to be used.

# Connecting Theory, Methodology and Domain

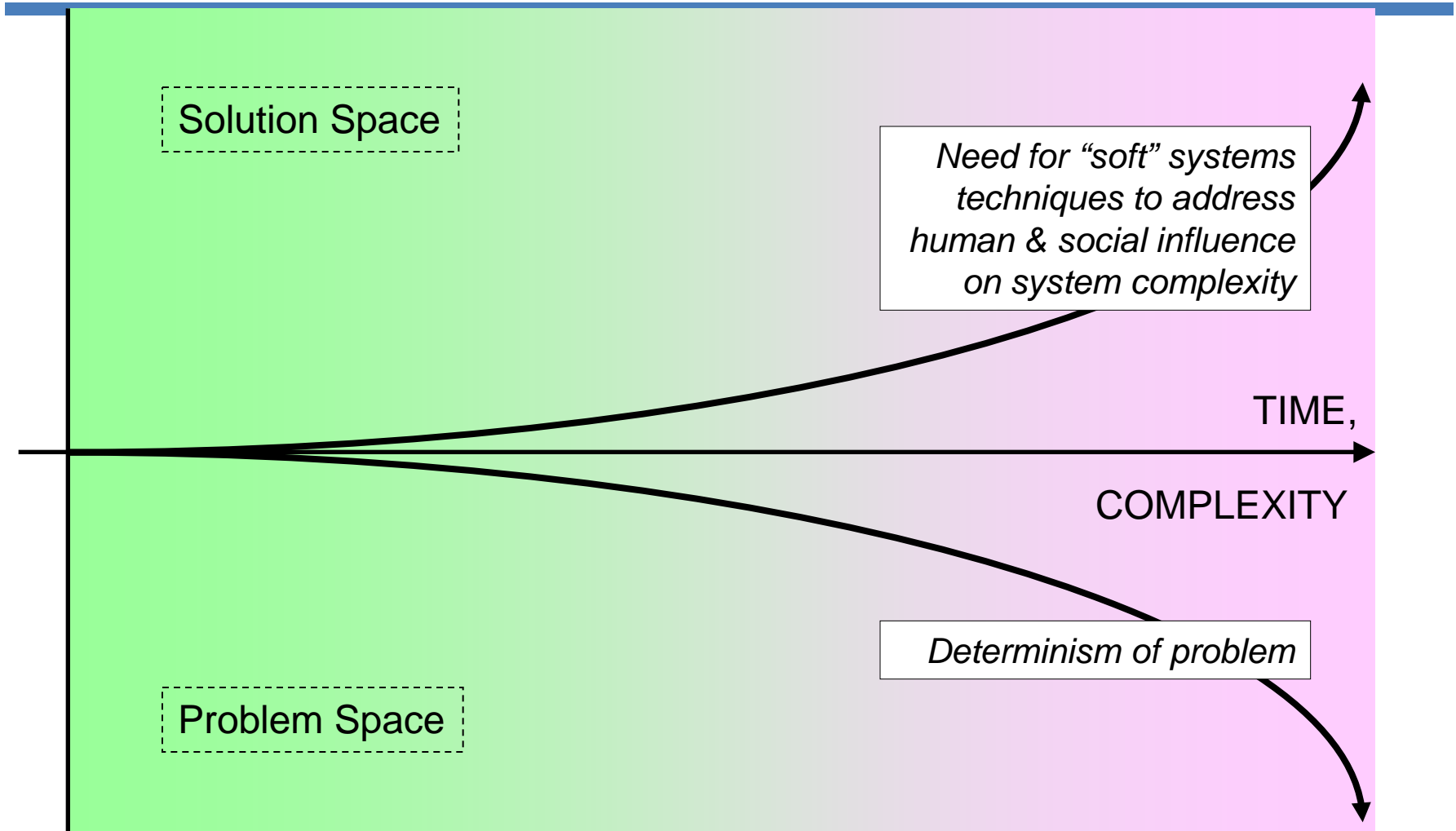
- Systems approach / theory should be consistent with the problem domain and context
- Methodology should be consistent with the theory upon which it is based
- The research output – should be relevant and useful in the problem domain



# Types of Systems Engineering (in Defence)



# Types of Systems Engineering (in Defence)



# Implications for Researchers

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- Exploit the opportunities:
    - Don't be restricted to hard approaches
    - Consider hybrid approaches that leverage strengths of both soft and hard approaches
- BUT
- Do so within a framework which is philosophically consistent

# Findings from SEAnet

- The range of methodologies and methods available to SE researchers is limited by doctoral education
  - Most doctoral advisors do not teach research methods; those that do tend to emphasize their own preferences
  - Some doctoral students simply accept this and proceed with their research plan with a single perspective
    - Probably the shortest path to the dissertation
    - But may be inappropriate for the problem domain being addressed.
  - Others seek research training beyond their home departments.
    - An innovative alternative
    - Potentially leads to a better domain-approach-methodology fit
- [Rhodes & Valerdi 2007].

# Challenges: Standard of Proof

- Very different expectations for ‘rigorous research’ between engineering and the social sciences
- Testing the effects of a new systems engineering technique or tool cannot be done in a laboratory with a control group / treatment group
  - Systems engineering is an activity performed in the context of a product or service for a paying client
    - SE efforts cannot be analyzed as objects to be inspected and described
    - Interactions with users / stakeholders are complex
    - Sophisticated methodologies are needed to analyze and predict outcomes of system creation and deployment

Ferris, Cook & Honour [2005]



# Challenges for the broader SE Research Community

- Where the degree is being sought in an engineering (not social science) school:
  - Solid justification must be provided for the choice of methodology and method
  - The doctoral committee may need to be supplemented with methodological expertise
- Journal editors and reviewers must both allow and encourage the application of new research perspectives
  - Initially accepting that we may not have the expertise to properly evaluate such work
  - Over time, building new SE research momentum beyond the hard engineering sciences

# Conclusions

- It is counterproductive to pursue research in a way that ignores methodological considerations
- Tackling the lack of methodological rigour in systems engineering requires a significant risk and experimentation
  - Opportunities exist to introduce soft and hybrid approaches to give a better domain-approach-methodology fit
  - But the community needs to adapt to accommodate new approaches
- The transition will not happen overnight, but is essential for the discipline...  
... and has to start somewhere...

# Questions?

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