INCOSE International Symposium
Philadelphia, PA
June 24-27, 2013

Steampunk System of Systems Engineering

A case study of successful System of Systems engineering in 19th century Britain

The Authors

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Presentation Overview

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- Background and introductions
- Overview of GB rail from 1830 - 2011
- Three frameworks
  - DOD
  - SOSA
  - DfT
- Summary, conclusions and further work

Growth in System of Systems

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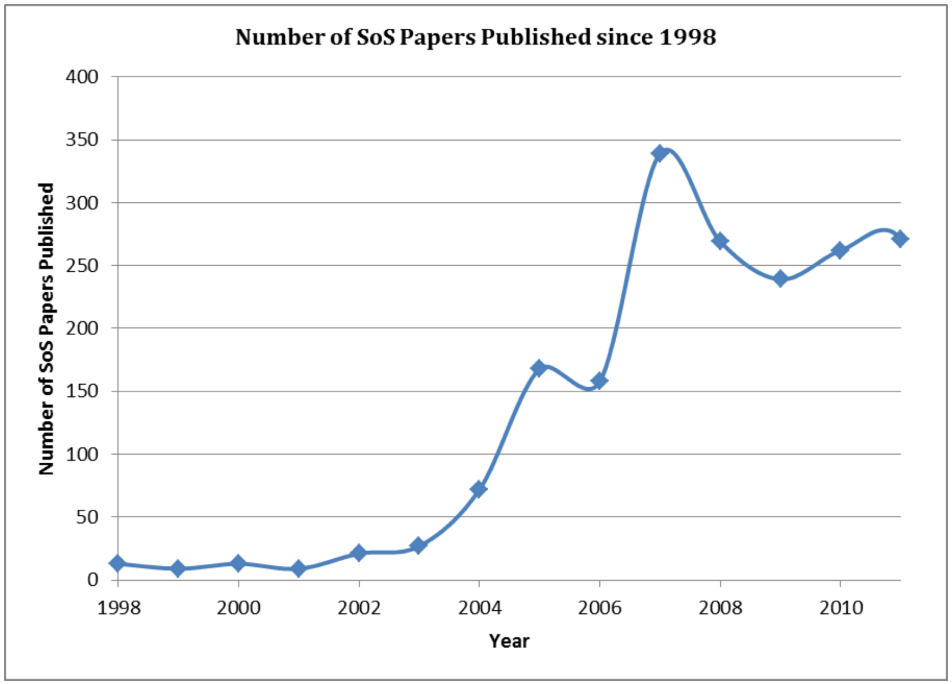

- Massive growth in SoS papers
- The big 'new thing' in systems engineering
- … or is it

A Uniquely 21Century Problem?

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SoS characteristics	Characteristics of early GB rail
Managerial, development and operational independence	150 railways with separate owners and operators
Rapid requirement development	Rapid growth of network, services and passengers
Multiple disparate stakeholders often with conflicting needs with little incentive to work together	Passengers, cities, shareholders, government, suppliers each with different needs
Emergence resulting from the inter–system interactions	Emergence of cross network travel opportunities
Often the systems are geographically dispersed and are connected through a network	Spread across the whole country – and connected through a (rail) network

Steampunk SoS Engineering

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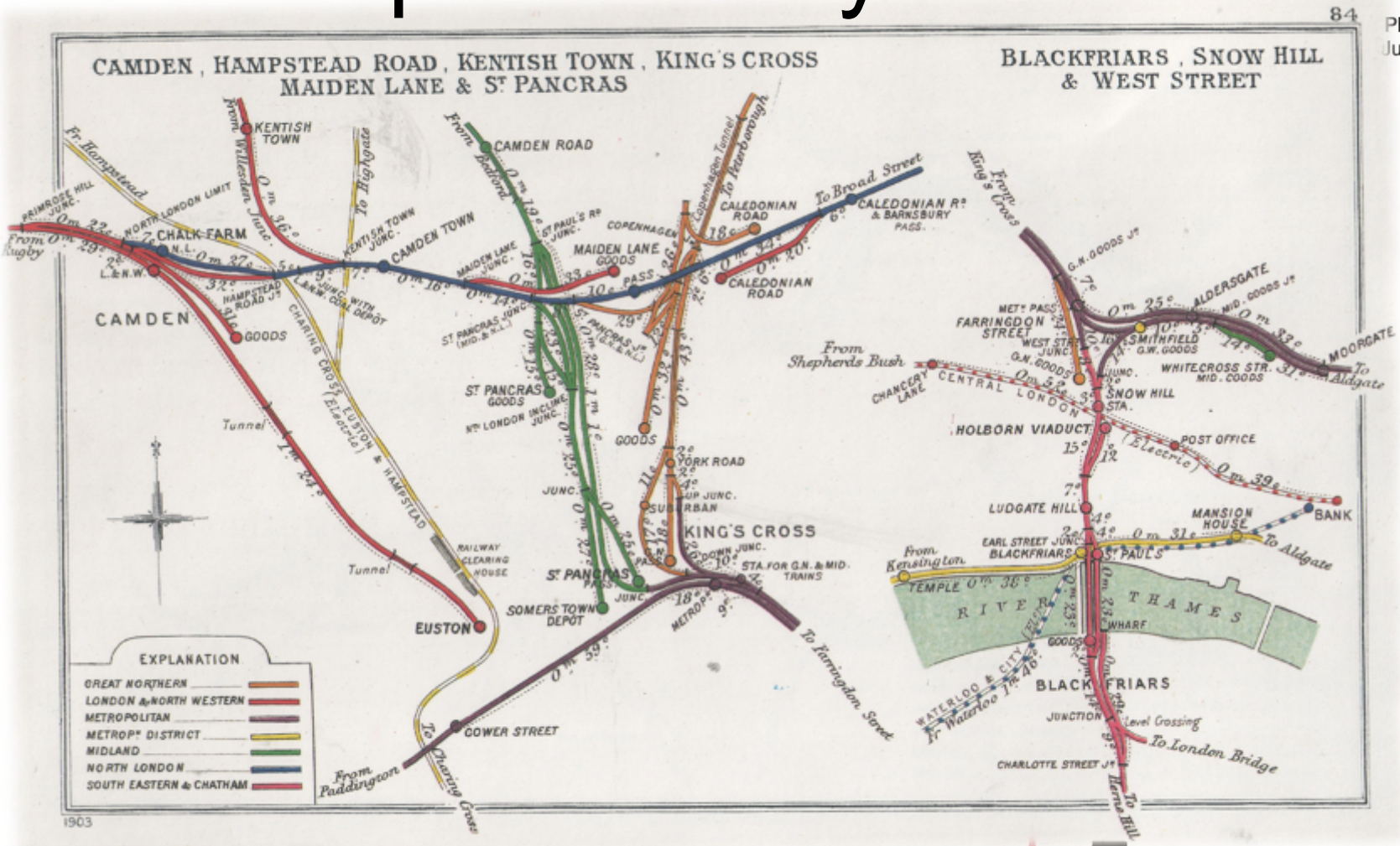
System of systems engineering is not new

SoS are not unprecedented

So how good are our current techniques at identifying what drove the development of GB rail?

Steampunk is a fusion of 19th century style and science fiction - Just like this case study

Independent Systems



Towards SoS

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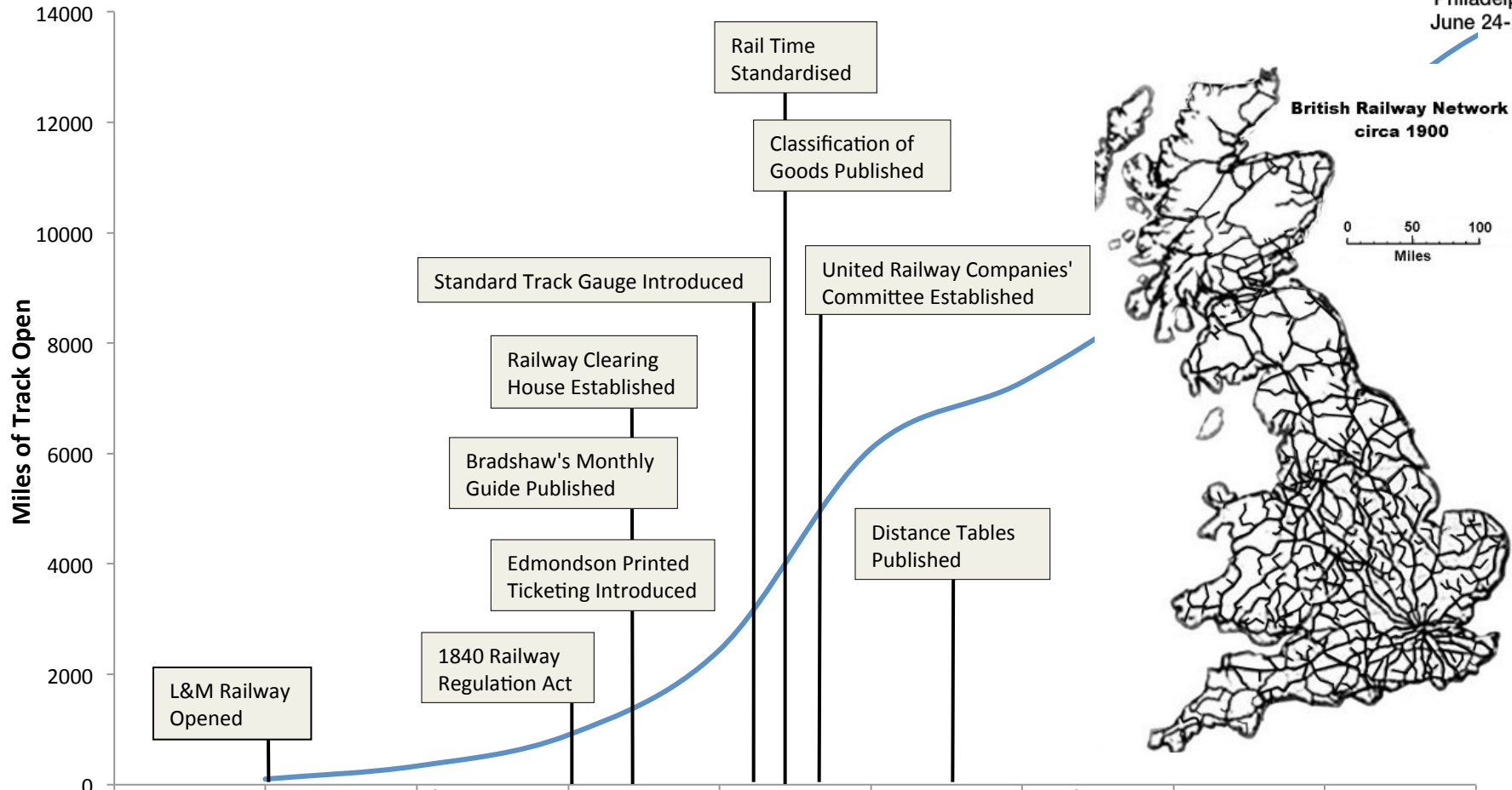

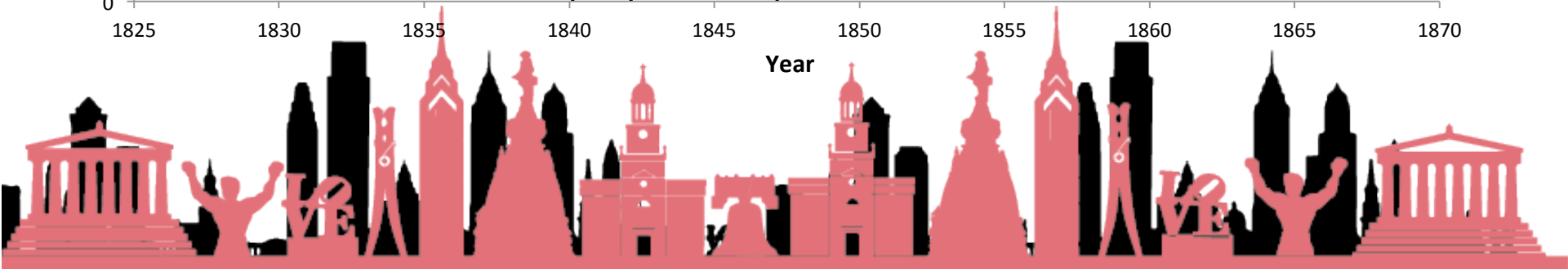

One System

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- First World War – Railways placed under Government control
- Remaining companies grouped into the 'Big Four'
- Second World War – 'Big Four' amalgamated

- 1948 – Rail network nationalised, publicly operated by British Rail
- 1994-1997 – Rail network privatised, privately operated by Railtrack
- 2002 – Infrastructure returned to State, under Network Rail

Three Frameworks

- The US DoD SoS classification
- UK MOD SoS Approach
- DfT assurance framework

DoD SoS Classification

Taken from Systems Engineering for System of Systems (Abbreviate Version) Version 1.0 8th July 2009

Type	Definition
Virtual	Virtual SoS lack a central management authority and a centrally agreed upon purpose for the system-of-systems. Large-scale behavior emerges—and may be desirable—but this type of SoS must rely upon relatively invisible mechanisms to maintain it.
Collaborative	In collaborative SoS the component systems interact more or less voluntarily to fulfill agreed upon central purposes.
Acknowledged	Acknowledged SoS have recognized objectives, a designated manager, and resources for the SoS; however, the constituent systems retain their independent ownership, objectives, funding, and development and sustainment approaches. Changes in the systems are based on collaboration between the SoS and the system.
Directed	Directed SoS are those in which the integrated system-of-systems is built and managed to fulfill specific purposes. It is centrally managed during long-term operation to continue to fulfill those purposes as well as any new ones the system owners might wish to address. The component systems maintain an ability to operate independently, but their normal operational mode is subordinated to the central managed purpose.

DoD SoS Classification

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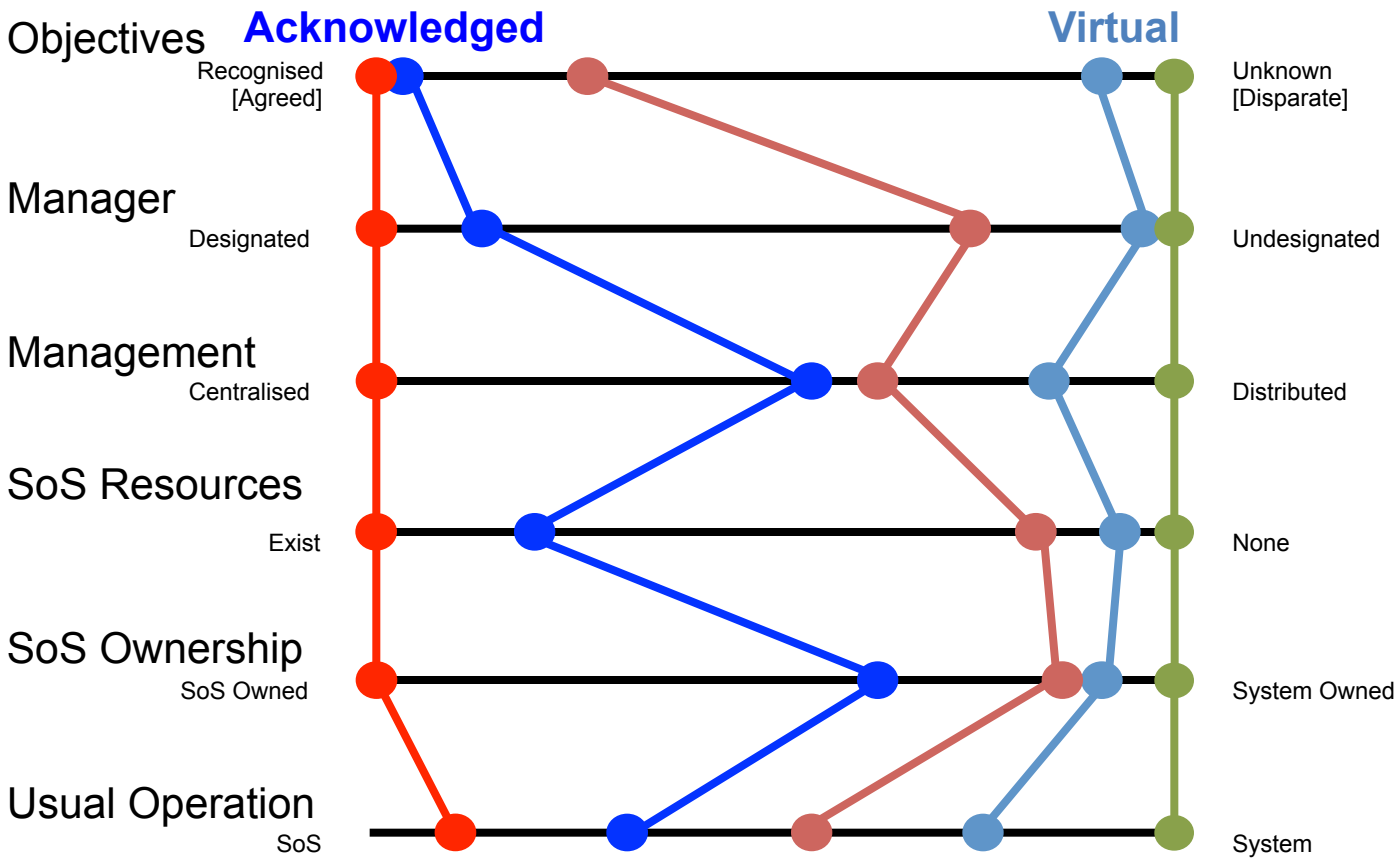

DoD SoS Classification

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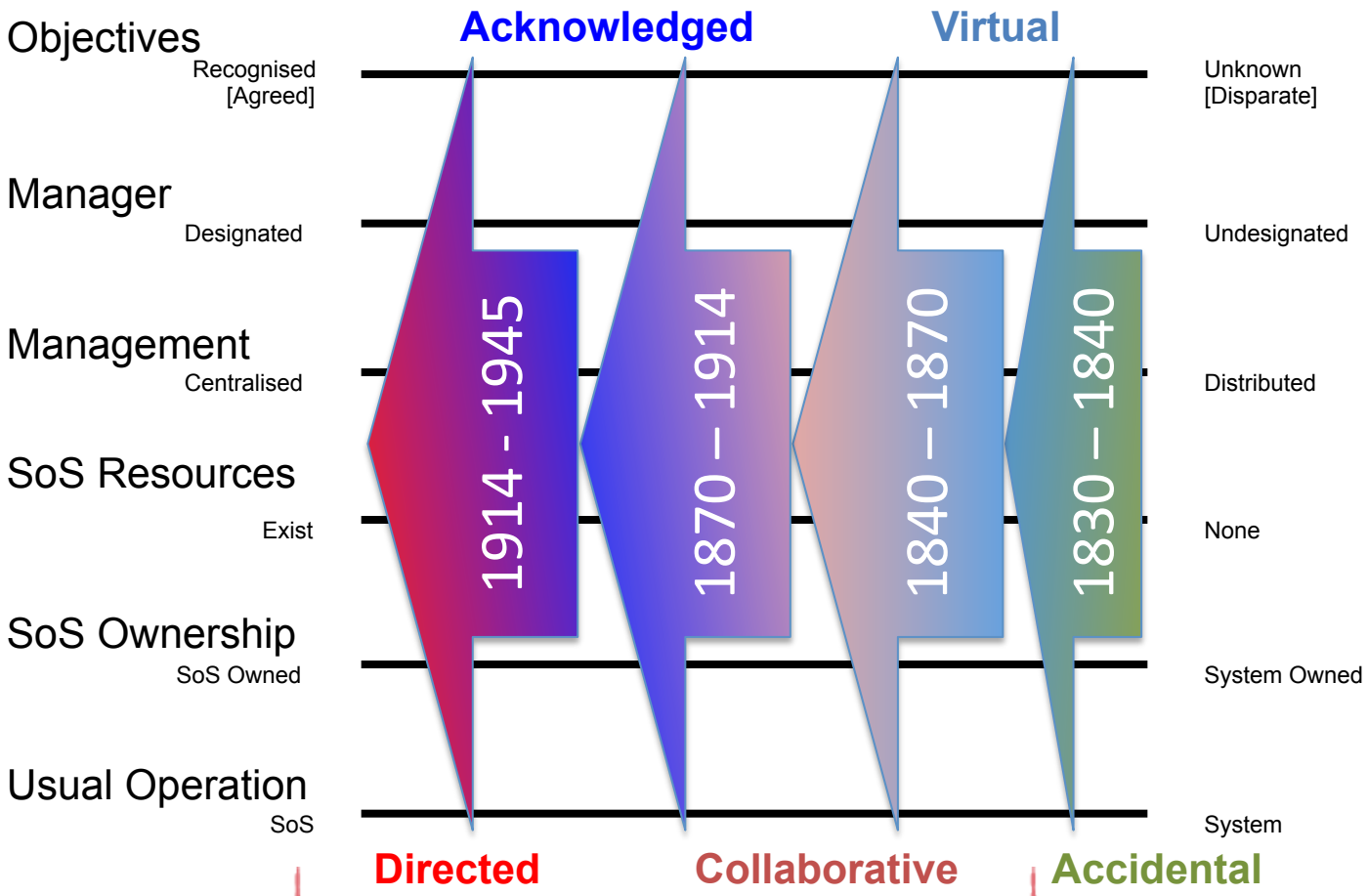

Findings on the DoD Model

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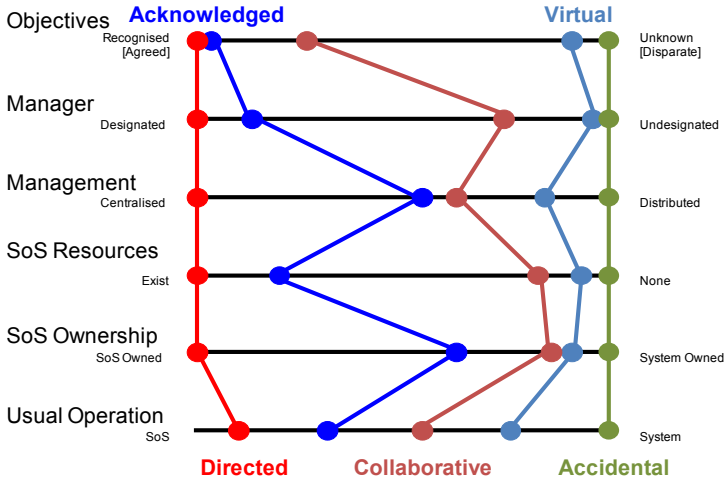
- Overall the differentiators, and to a lesser extent the DoD classes, seem to be a useful way of thinking about the evolution of the SoS.
- Neither the model, or the rail network, required high levels of technical interoperability.
- The model seems to be missing an element on customer planning or customer pull.
- GB rail was not a useful SoS until it became collaborative.



UK MoD System of Systems Approach (SOSA)

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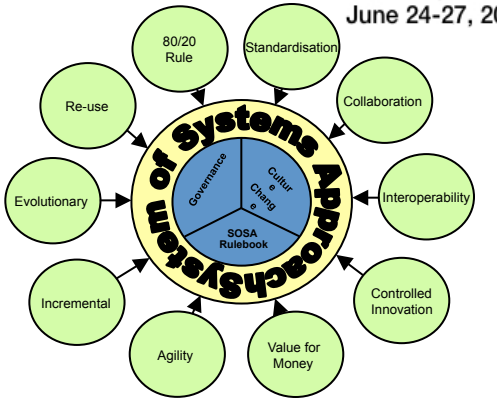
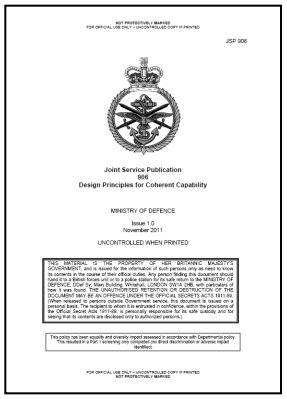
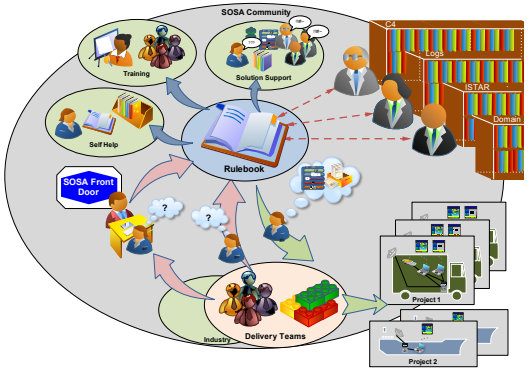
"Enabling enhanced capability through achieving commonality, reuse and the interoperability of independently procured systems"



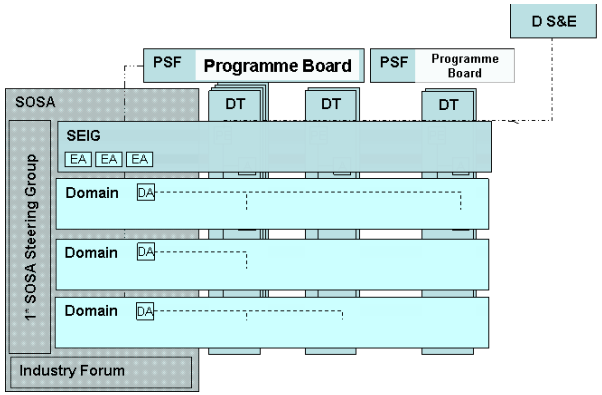
Principles



Rulebook



Operating Model



Drivers:

- Cultural & Behavioural Change
- Practical Guidance to plan, deliver and operate coherent interoperable components of capability

UK MOD SOSA Principles

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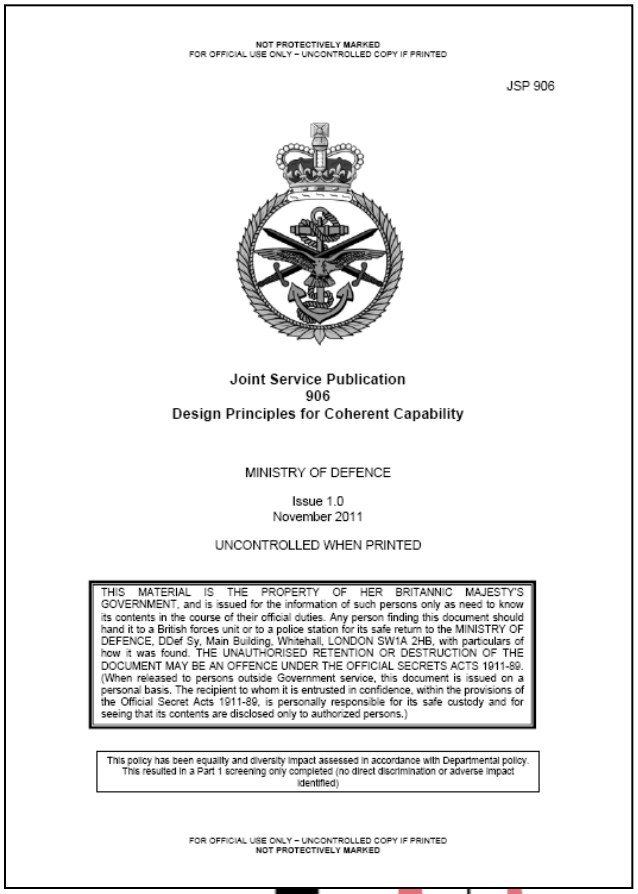

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Joint Service Publication
906
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Issue 1.0
November 2011

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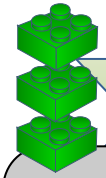
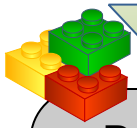
Business Drivers

- Unifying the Business
- Driving Business & Operational Effectiveness
- Minimising Diversity



Reuse

- Design for Reuse
- Building with Proven Solutions
- Ensuring Commonality of Services across the Enterprise



Interoperability

- Designing for Flexible Interoperability
- Conforming to Open Standards
- Treating design information as an asset

Findings on MoD SOSA

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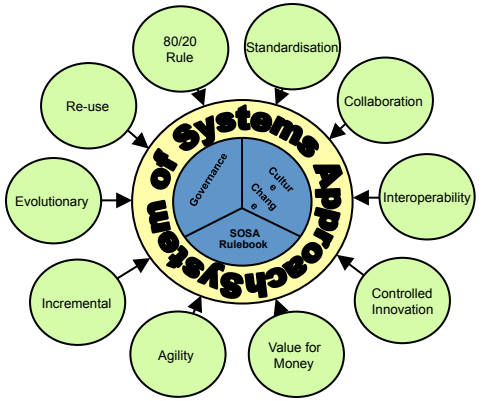
- The fact that the railway was a collaborative SoS made some of the principles (for example P1 ‘unifying the enterprise’) less relevant.
- Some of the principles, especially those involved in clarity of business value (P2 and P6) were highly relevant.
- Some of the principles (P3-P5) follow a strong centralist ‘command and control’ model that was alien to the free market model that the railways were founded on.
- Principle 9 was not adopted by the railway, but in hindsight should have been!
- A range of principles (P8 and to a lesser extent P3-P5) were adopted as the railways moved from a period of innovation and growth (in the 19th century) to one of cost reduction (in the 20th century).



DfT Assurance Framework

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- Developed by the UK Department for Transport following Rail Value for Money study
- Used to evaluate systems engineering effectiveness within the department's wider Project, Programme and Portfolio Management approach
- DfT spends £2Bn-£3Bn p.a. on rail capability upgrades

DfT Assurance Framework

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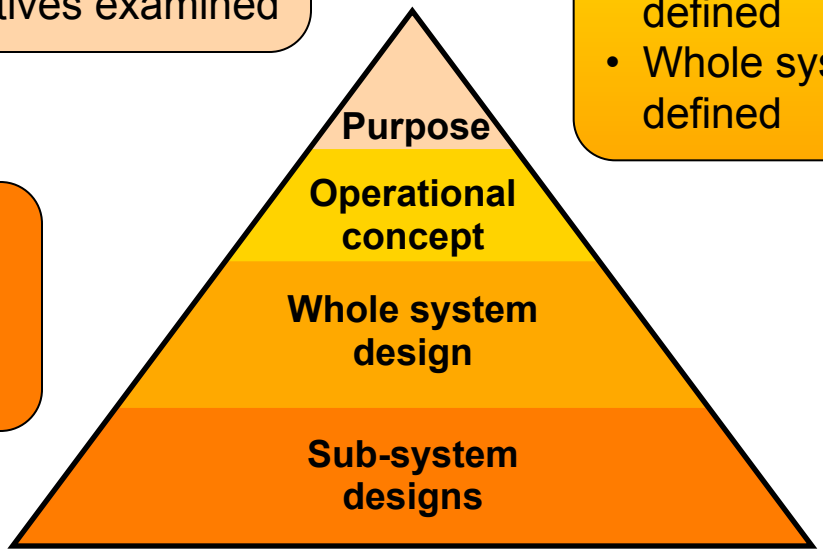
- Purpose and outcomes defined
- Benefits agreed
- Alternatives examined

- Operational concept defined
- Whole system solution defined



- Requirements clear and managed
- Interfaces clear and well managed

- Critical technologies understood
- Build installation and transition arrangements suitable
- Support arrangements suitable

- Everything in a plan and being managed

Findings on DfT Framework

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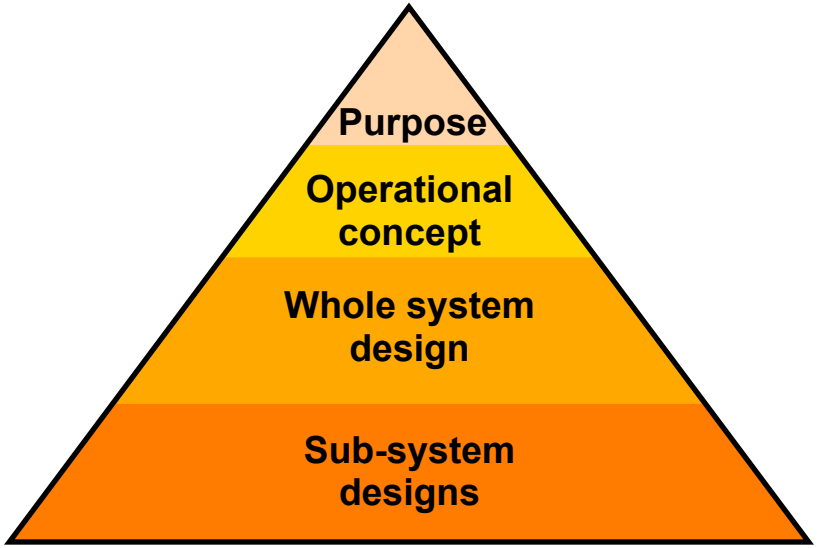
- Useful predictive framework for specific SoS interventions
- Like SOSA framework, assumes directed SoS
- Despite this, they appear to be useful predictor of the utility of changes to the SoS.
- The questions do, however require a fair degree of interpretation as they assume a significantly greater systems engineering capability that existed in the mid 19th century!



Discussion and Findings (1)

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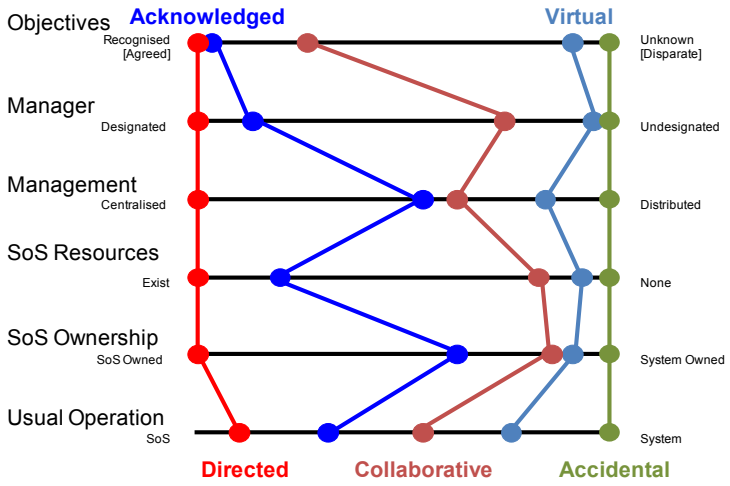
- This is just one case study
- Just three frameworks (but others exist?)
- US DoD SoS classification a useful language to discuss SoS
- GB rail evolved through several stages
  - 150 individual private sector systems in the 1840s
  - A collaborative private sector SoS by the 1870s
  - A single state owned directed system in the late 1940s
  - A vertically segmented collaborative SoS in the late 1990s
  - A slightly more integrated acknowledged SoS in the early 2010s



Discussion and Findings (2)

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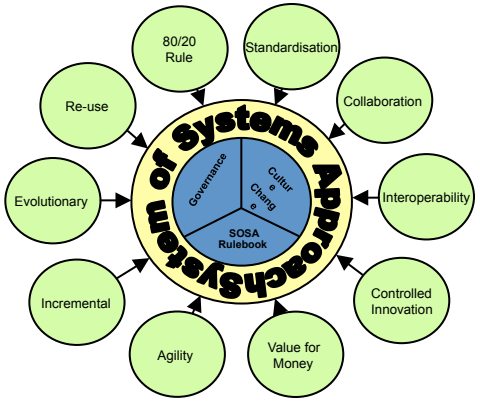
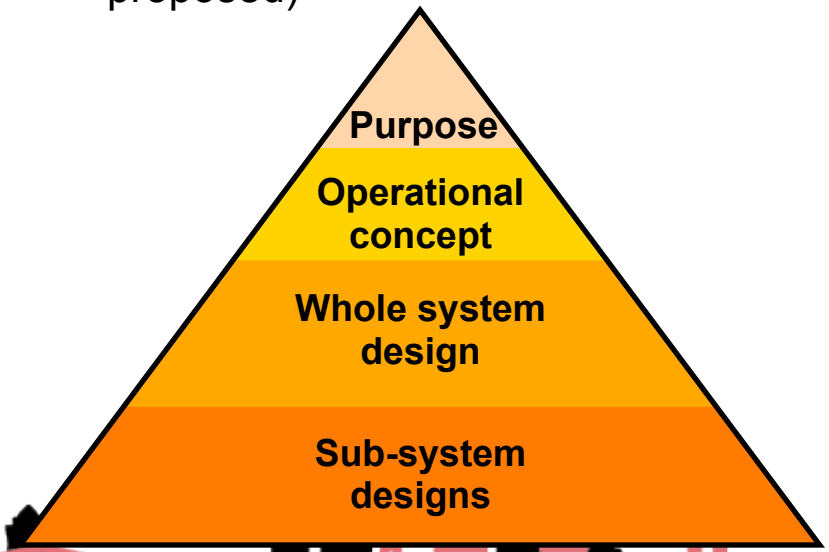
- Both SOSA and the DfT assurance framework assumed an acknowledged or directed SoS
- Both SOSA and the DfT assurance frameworks downplayed the importance of aligned economic incentives (additional SOSA principles and assurance questions have been proposed)





- Total technical standardisation is not required to deliver an effective SoS. A fairly low level of standardisation was required to deliver a basic capability.
- Where there is sufficient economic pull, there will be an operational work round, even if there is no technical solution.

Possible Future Work

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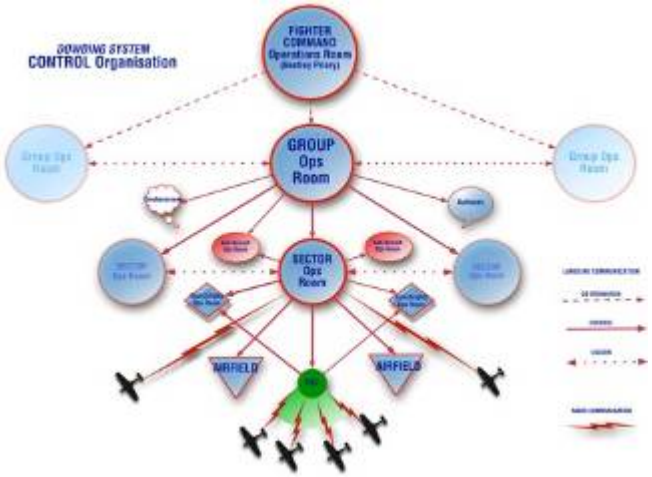
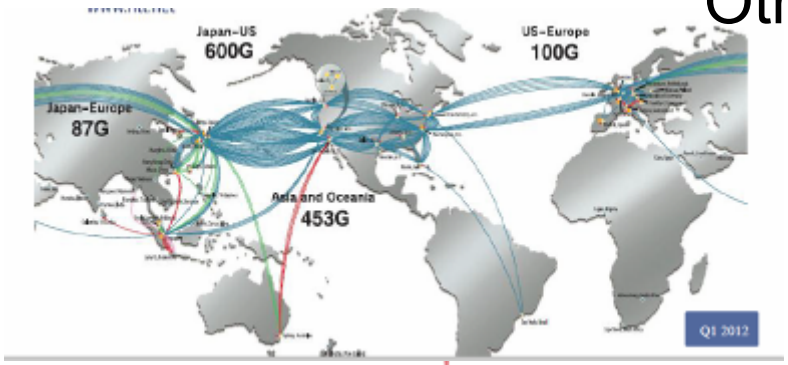


Other case studies

Other frameworks



Conclusions

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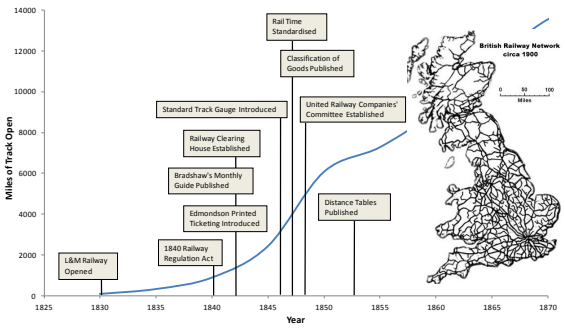
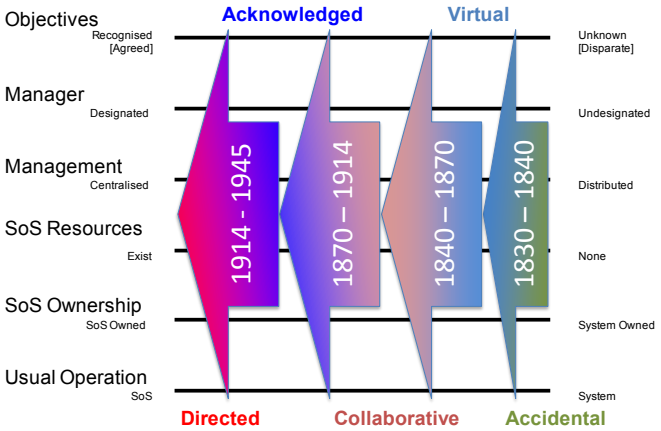
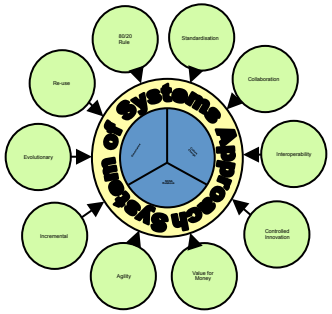
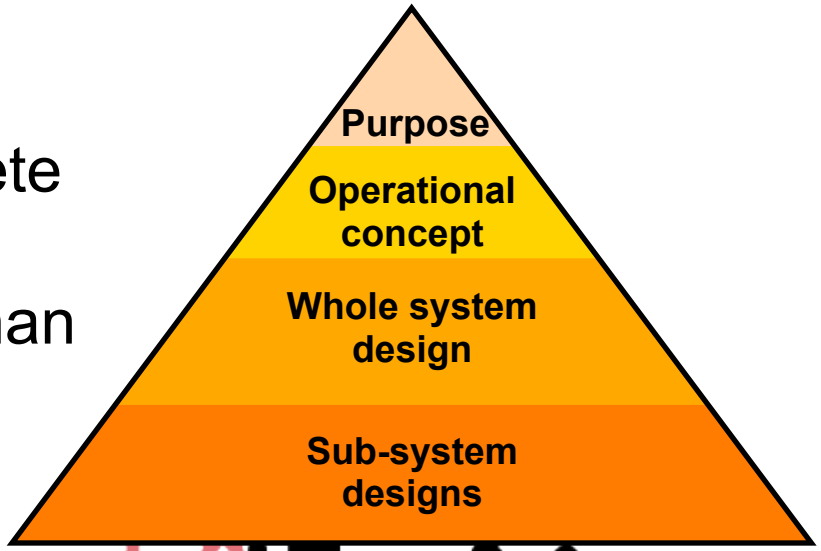






None of the frameworks are complete

Economic drivers more important than technical interoperability



Any questions?

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