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Realising the Value of Systems Engineering

Richard Beasley
Rolls-Royce plc
Richard.beasley@rolls-royce.com
@richbsys

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3. What is Systems Engineering, and why is implementing hard
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1: Importance of Engineering / Systems

HRH Prince Philip

Founder of Royal Academy of Engineering (1976)

"Somehow or other that balance to try and fit as many people on to this globe as comfortably as possible without them doing too much damage - I think ultimately it's going to be engineers who are going to decide that"

"Everything that wasn't invented by God is invented by an engineer"

"Engineering is the only way to make new ideas relevant"

BBC radio 4 interview, Jan 2016

Importance of Systems (that work)

ROYAL ACADEMY OF ENGINEERING

- Engineering systems, and the problems that they seek to solve, are becoming more complex.
- It is not possible to design part of the system in isolation without considering the problem and its solution as a whole.
- This spans professional disciplines –and it reaches outside the technical domain to encompass the environment of the system

From "Creating Systems That Work" (2007)

INCOSE

The systems of the future

- Need to respond to an ever growing and diverse spectrum of societal needs in order to create value
- Need to become smarter, self-organised, sustainable, resource-efficient, robust and safe in order to meet stakeholder demands

From "A world in Motion – Systems Engineering Vision 2025 (2014)

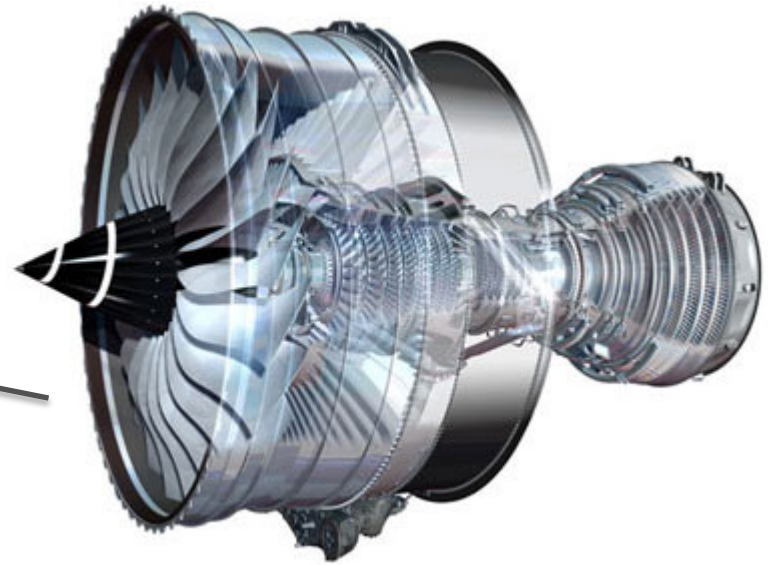
2: Examples of systems

In the following examples

- System overview given
- Explanation of Systems approach used (implicitly or explicitly)
- Benefits gained

Examples from several domains to show ubiquity of the approach

Airbus A350 with Rolls-Royce Trent XWB



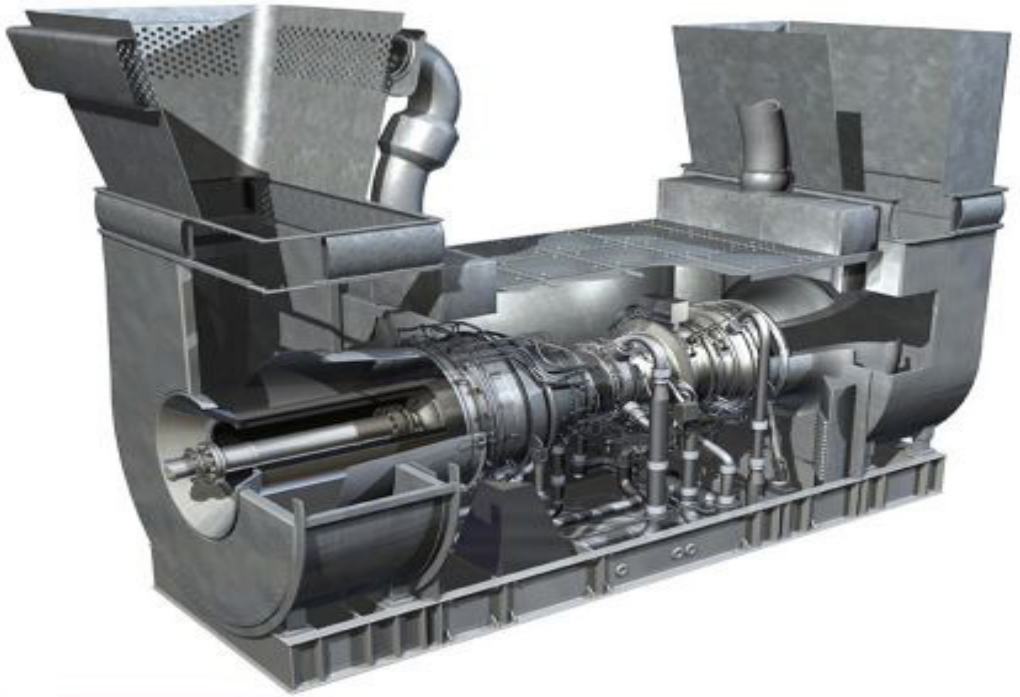
Rolls-Royce Trent XWB

Systems points

- Multiple stakeholders
- Safety key issue, but many other important attributes
- Millions of parts
- Made up of layers, sub-systems, sub-elements and components
- Perfect example of application of product definition lifecycle (INCOSE handbook) and the product structure V
- Systems Engineering explicitly used
- Large cost of rework if system doesn’t work

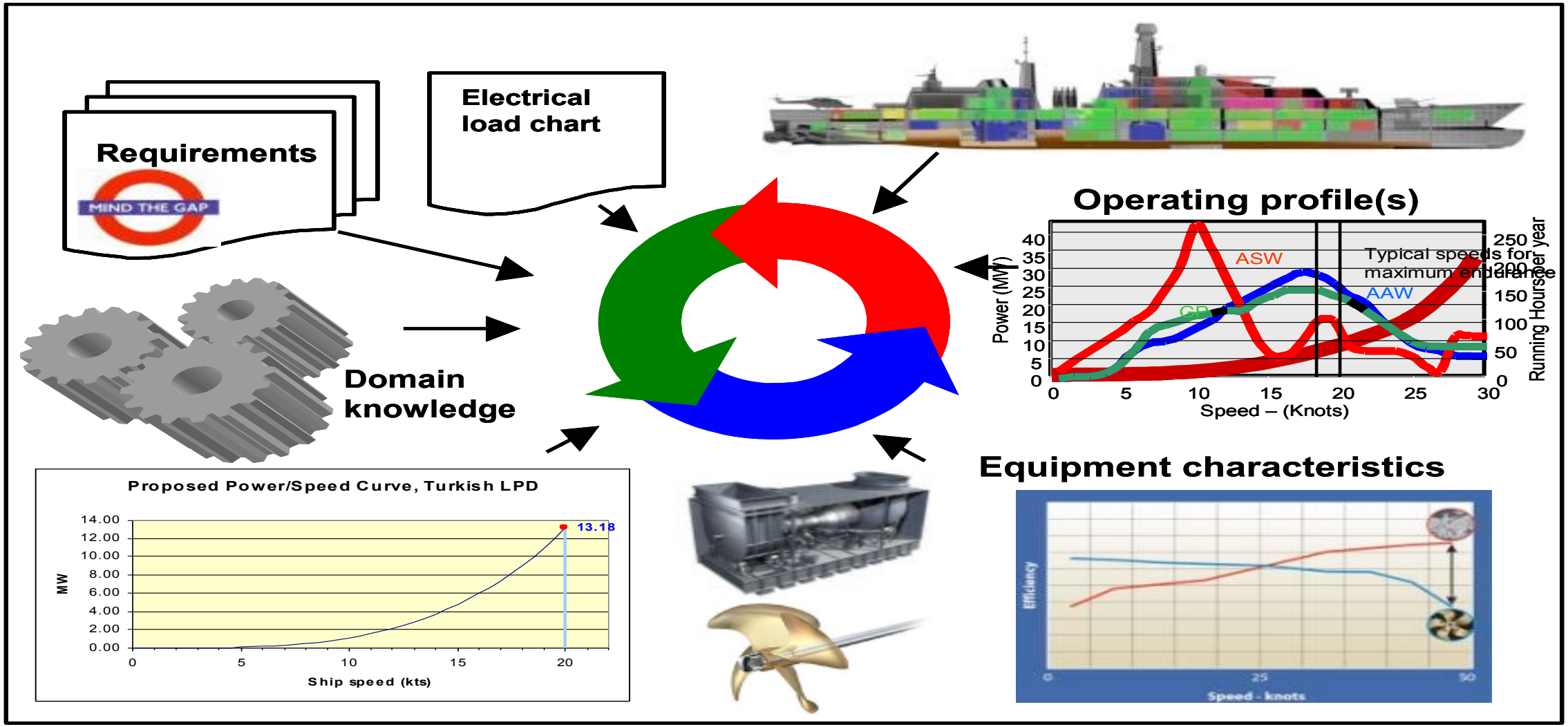
Naval example

- Power provision for the QE2 Aircraft Carrier (new ships for Royal Navy)



MT30 powerplant (marine derivative of Aero Trent 800)

Factors affecting System selection



From Beasley, R. and Partridge, R. (2011), 11.3.2 *The Three Ts of Systems Engineering – Trading*, *Tailoring*, and *Thinking*. INCOSE International Symposium,

Systems approach taken

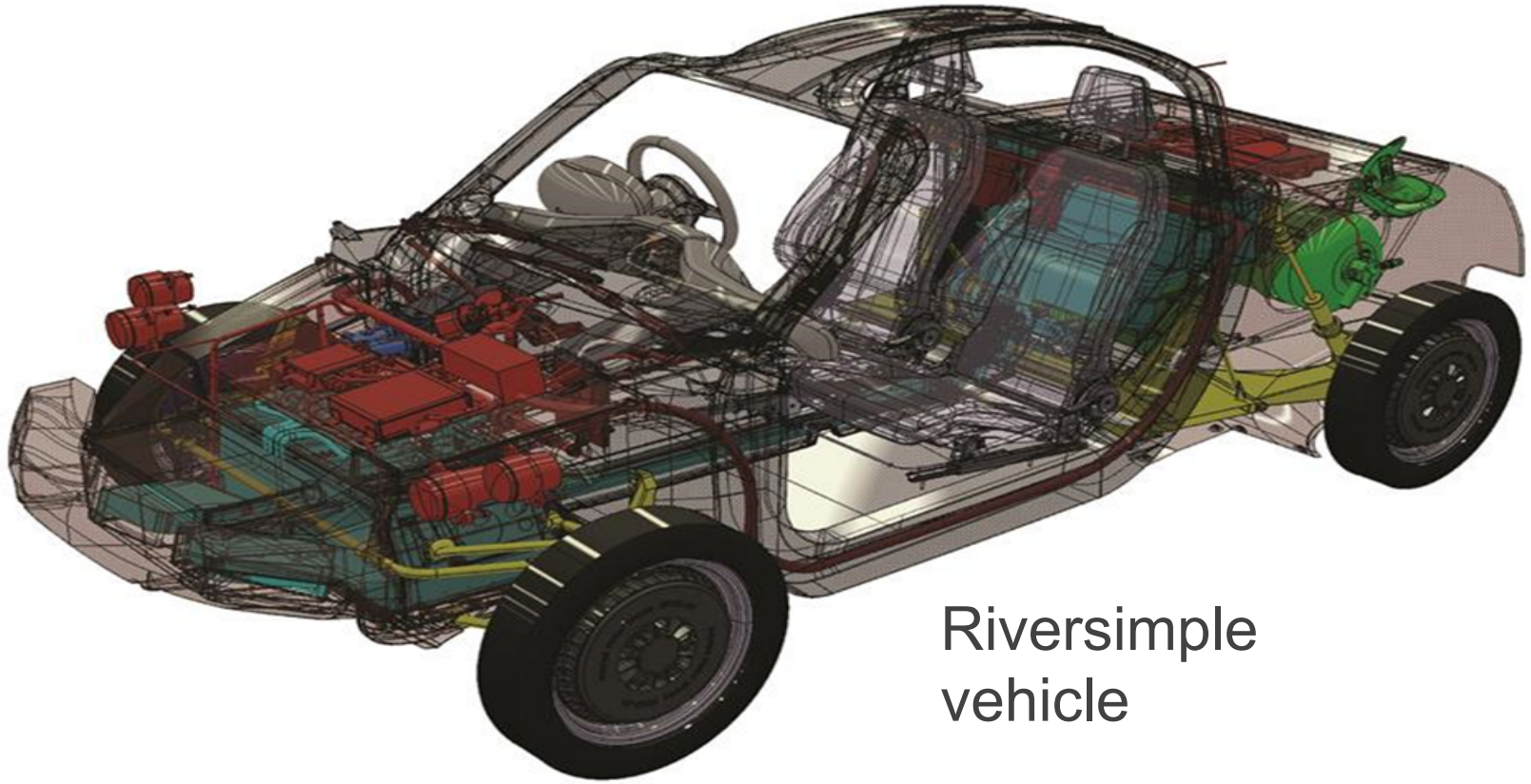
Began with generation of over 50 concepts, coarse sift yielded nine “viable” systems, and assessed against ability to physically fit. This left 5 concepts, to which following process applied

1. Development of assessment criteria
2. Develop weightings for criteria
3. Determine a metric per criteria per system using objective methodology
4. Develop the scoring system
5. Derive the result

Prime mover selection then reviewed using an independent tool – same decision reached

From Beasley, R. and Partridge, R. (2011), 11.3.2 *The Three Ts of Systems Engineering – Trading*, *Tailoring*, and *Thinking*. INCOSE International Symposium,

The Rasa Car design practice



Riversimple vehicle

"*We began with a hydrogen fuel cell, a manifesto for sustainable design and a blank sheet of paper*"
Tabula Rasa means 'clean slate' in Latin

see www.riversimple.com
@riversimple

Original source on Rasa - Fryer, T, 2016 *The peoples car – not for sale!,*
http://www.eurekamagazine.co.uk/design-engineering-features/technology/the-peoples-car-not-for-sale/116630/

Batteries or hydrogen?

- Riversimple describe themselves as a sustainable car company, not a hydrogen car company
- The question “batteries or hydrogen” is the wrong one. The answer is neither exclusively
- As HL Mencken said:

“***For every complex problem there is an answer that is clear, simple, and wrong***”

Whole system design

The ideas / rationale behind the design include:

- "**Well to wheel emissions**" – total emissions consideration
- **Power demand analysis**, decoupling cruising and acceleration, led to an 8kW fuel cell, (comparable cars might have 100kW), and super capacitors for acceleration.
- **Finding virtuous circles** – e.g. exploitation of synergies in weight
- **Sell mobility** – customers buy service that will include ALL costs of motoring, including fuel.
- **Infrastructure needs** (e.g. hydrogen fuel) addressed by cars introduced to an area serviced by one fuelling station. Expand gradually without large initial investment.

They may call it "Whole System design", but it is a Systems Engineering

London Heathrow Terminal 5

- A £4.3bn mega construction project
- 6 year construction project delivered on time and on budget
- Opened in 2008
- Main building is the largest free-standing structure in the UK
- One “glitch” on opening – see next slide

Systems and T5

- The Civil Engineering / Infrastructure was done following a Systems Engineering approach
  - "Doing it Differently" – Prof Patrick Godfrey
  - Lots of focus on pro-active risk identification and realising the importance of recognising uncertainty
- Focus on primary function of terminal to be "interchange" in journey, so design of T5 focuses on flow
- Approach taken to allow time to integrate "building" and "operation" systems – to reduce risks of integration
- Failure to do this led to the baggage system failure on opening day, which is what was reported in media
- System robust – problem resolved / recovered within a month

See Godfrey, P, 2007 *Systems Thinking about Mega Construction Projects,* lecture to INCOSE UK Bristol Local Group, 26 September 2007, available (to all) online at http://www.incoseonline.org.uk/Documents/Bristol/BLG070926_Systems_thinking_about_Mega_projects.pdf

Summary of Value of Systems Engineering in these examples

- **Understanding all stakeholder views** – ultimately giving full lifecycle consideration and an alignment of all interests.
- **Optimising the whole not the parts** – using structured architecture, designing sub-systems and elements in the context of the whole.
- **Clear focus on requirements** – both for verification and validation of the solution (to ensure safe and reliable entry into service), and for decision rationale.
- **Recognising key issues, uncertainties and risks** early in lifecycle, so there can be pre-work not re-work to prevent cost and schedule over-runs.
- **Focus on purpose rather than purely the solution object**.

The Systems Engineering approach can be seen in all of these examples, but it is not always explicitly described as Systems Engineering (especially in the way INCOSE describes it).

3: Overview of Systems Engineering and barriers to implementation

So if Systems Engineering is so valuable….

Why isn't it used more widely / generally?

So what is Systems Engineering, and what are key problems?

The way it is described #1

INCOSE defines Systems Engineering

- Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem
- Systems Engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs.

And the way of doing it – INCOSE Systems Engineering Handbook

It includes statement

- *"SE can be applied on any size or type of system. However this does not mean it should be blindly applied in the same fashion on every system"*

The way it is described #2

- Systems Engineering is an approach, hard to describe
- There are many descriptions of Systems Engineering, some that confuse.
- Here are 2 more (of the better ones!)
  - *Systems Engineering focuses on solving some of the most complex engineering challenges. It does this by collecting and organizing all the information needed to understand the whole problem, exploring it from all angles, and then finding the most appropriate solution*

    UK apprentice standard, SE masters level, 2015

    For 1st definition see- UK Government, 2015, – *Apprenticeship Standard: Systems Engineering masters level* – see https://www.gov.uk/government/publications/apprenticeship-standard-systems-engineering

  - *Systems Engineering is the systematic application of Systems Thinking*

    Stuart Burge – Systems Engineering short course – see www.burgehugheswalsh.co.uk

The nature of the value

- Much of the value of Systems Engineering comes from preventing rework
  - **But this is spending money (up front) to save money project does not plan to spend**
- It is not the “traditional” way engineering is done
  - Madness can be defined as “**repeating the same thing, but expecting a different answer**”!
  - **Many project teams think they have “learnt lessons”, but their approach prevents one failure, but allows new ones**

Its not only process (or only thinking)

Being Systematic			
	Good process	**No invention / rework** No real thinking, Systems process reduced to “by the numbers”, ineffective Systems Engineering	**A very good chance** The right understanding of problem – skilled and appropriate use of process and method
	Poor Process	**No chance** Cannot handle complexity and unlikely to do well!	**No control** Skilled individuals “uninterested” in process – so get no control, critical things not done, reinvention and some “maverick”
		Poor Systems Skills	**Good Systems Skills**
		Being Systemic	

From Beasley, R. (2012), *The Barriers to Systems Thinking*. INCOSE International Symposium

On what systems does this system depend?

Audience Participation
This is a test!

Applying Systems Thinking is hard
We all have filters

How long before you can switch between two images easily?

What do you see?

Young children see
Dolphins immediately

Uncertain about uncertainty

People don't like

- admitting being uncertain
- Looking for uncertainty

But

"One who doesn't know and doesn't know that he doesn't know

He will be eternally lost in his hopeless oblivion"

Ibn Yamin, Persian 13th century poet

See Behan, R and Perry, S., 2015, *Unravelling the Knowns and the Unknowns*, INCOSE UK ASEC 2015

4: Suggestions on Implementation of Systems Engineering

Avoid making it difficult

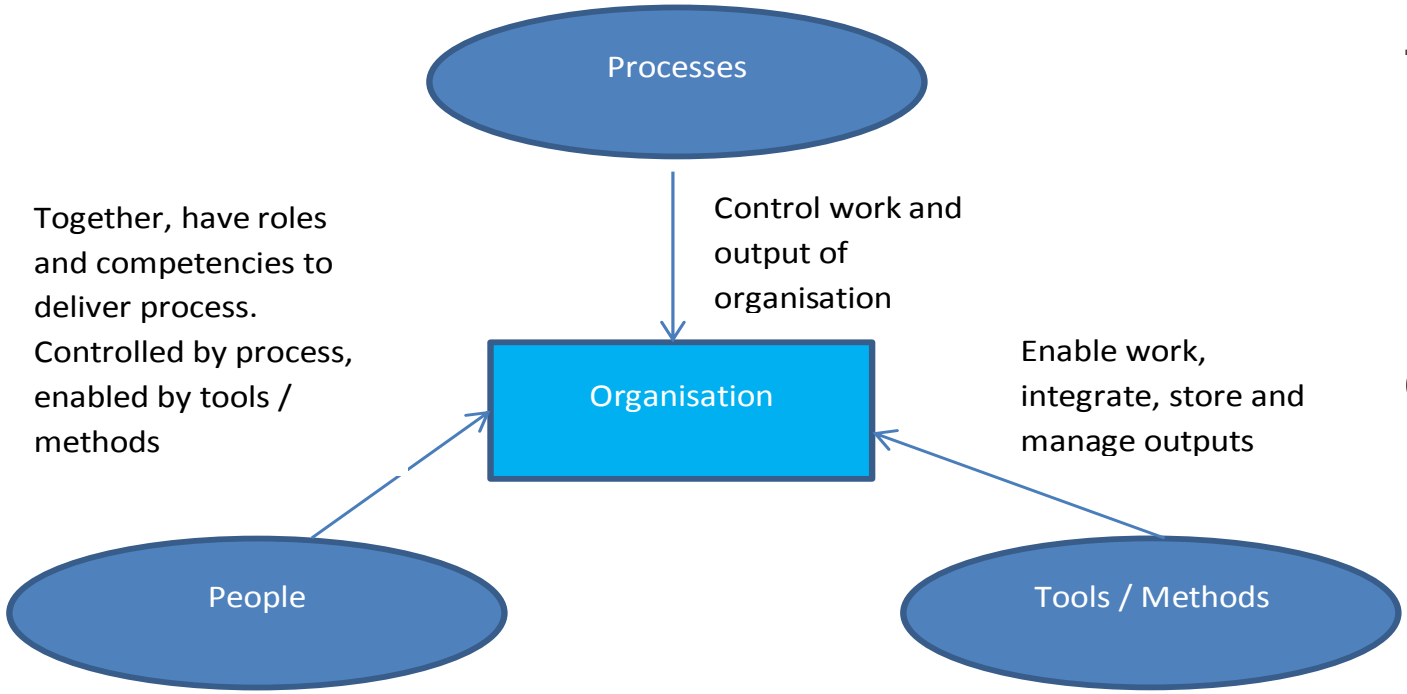
1) From “Creating Systems That Work”

There is a great deal of pointless and near-theological debate about system terminology….There is a continuum, from a single discipline engineer who nevertheless has to work in a multidisciplinary team, through an engineer who designs integrated systems, to one who specialises in the system aspects and is called a systems engineer

2) From “Making Systems Thinking Routine: Systems Engineering Improvement in RR plc” (Charlotte Dunford Thesis (Eng.D.) (2016)

“Perfection is the enemy of good”

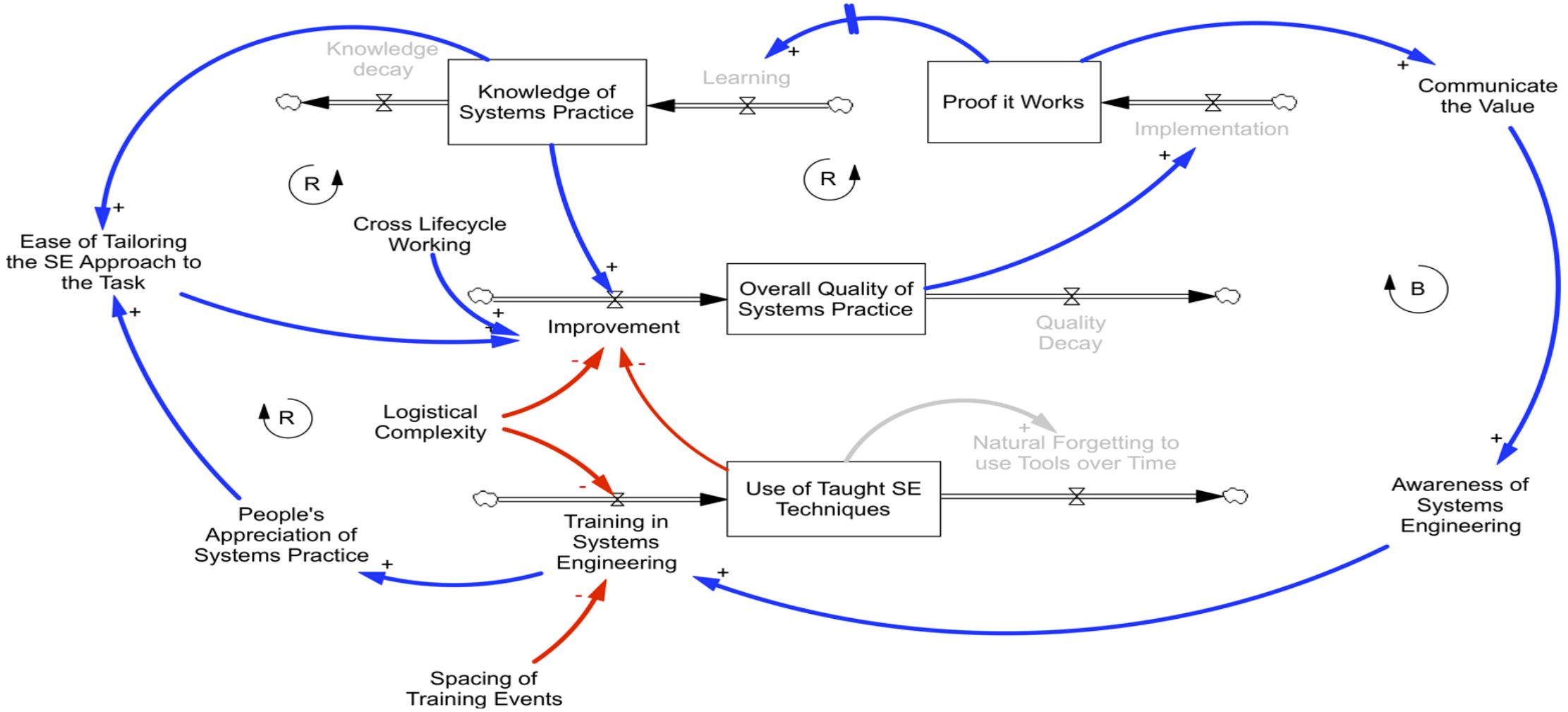
Organisation



The purpose of doing Systems Engineering is not to do Systems Engineering, but to increase probability of success of projects organisation undertakes

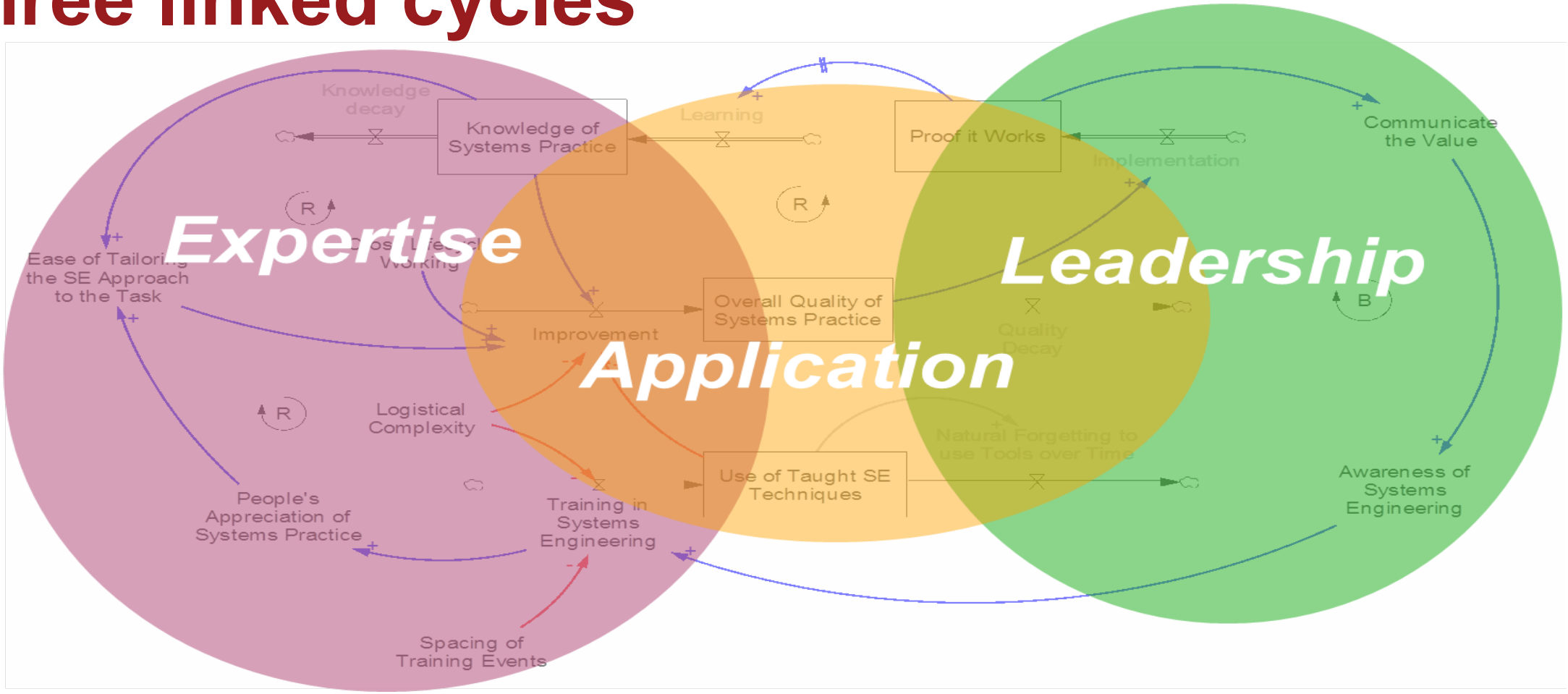
- I believe an organisation is a complex, socio-technical system
  - Each different
  - So each a prime case of application of "Systems Engineering" – to put the systems approach effectively at its core – to achieve value of Systems Engineering

System Dynamic diagram examining quality of System Practice



From Dunford, C. N., Yearworth, M., York, D. M. and Godfrey, P. (2013), "*A view of Systems Practice: Enabling quality in design.*" Syst. Engin.,16: 134–151. http://dx.doi/10.1002/sys.21220

Which simplifies to three linked cycles



Tips for implementation

- Make System Engineering “core”
  - “Make Systems Engineering the way <*insert organisation / project name here*> do Engineering”
- Be clear
  - Purpose of doing Systems engineering is not “to do Systems Engineering”, to to achieve better solution, with greater probability of success
- Implement gradually – not a “big bang”
  - Get Systems Thinking competency in all
  - Don’t push for “total” perfection
- Have specialist Systems Engineers
  - Advise on appropriate Systems approach, and facilitate
  - Detailed integration / modelling – to advice on gaps, uncertainty and inconsistency from all the disciplines
  - But do not become a “Systems Engineering silo”
- Encourage Emotional Intelligence in the System people

5th bullet – see Swales, S., Wright, J. Oxenham, D., 2012, *Systems Skills Development – the Yellow Brick Road Approach*, 3rd Annual IDC in Systems Research conference, Bristol University / Bath University Systems Centre, 22nd May 2012 – see http://www.bristol.ac.uk/media-library/sites/eng-systems-centre/migrated/documents/simon-swales.pdf

5: Conclusions

- Systems Engineering is ubiquitous, and can apply to work in any domain
- Systems Engineering approach provides value by:
  - Upfront understanding of needs, so solution definition work is done in context
  - Early recognition of uncertainty, assumptions and risk, increasing the probability of success
  - Abstract focus allows greater freedom and innovation
- Systems Engineering requires both a sound systematic process and the application of Systems Thinking.
- The purpose is not to do Systems Engineering, but to produce better systems / solutions utilizing Systems Engineering, so
  - Systems Engineering must be an integrated part of the whole – not become another silo.
  - integrated into the process, roles and methodology of the organization..
- Specialist Systems Engineers are needed –
  - tailor the systems approach to the specifics of the organization / problem type,
  - coaching / mentoring Systems Engineering amongst the engineering (and wider) team.
  - specialist experts in specific Systems Engineering activities

The world increasingly relies and needs well-engineered, big picture solutions. Systems Engineering approaches are critical to ensuring that these solutions are produced as needed

Summary

Systems Engineering can provide significant value

The value is ubiquitous across domains

But

- Many of the concepts of Systems Engineering are hard (to explain, to organise for, to do)
- It needs to be integrated into organisation, not a “separate, isolated discipline”

Questions?

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