The 3 T's of Systems Engineering
Trading, Tailoring and Thinking

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Defining Systems Engineering as part of Engineering

Implementing SE

- In Rolls-Royce a skill owner defines skills and knowledge needed in roles in skill
- Systems Engineering interacts with a **lot** of other skills
- Ambiguity -Systems Engineering is both
  - A thought process in many roles
  - Specific roles with high levels of specific systems competencies

Need to provide a clear definition of Systems Engineering.

SE definition #1

- **INCOSE** defines Systems Engineering as

"*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: Cost and Schedule, Performance, Test, Manufacturing, Training & Support, Operations and Disposal. 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*

providing a quality product that meets the user needs".

INCOSE What is Systems Engineering? Http://www.incose.org/practcie/whatissystemseng.aspx, June 2004

Good – but its scope could be applied to "traditional" engineering

What is different about Systems Engineering?

SE definition #2

An alternative definition is

- "Basically Systems Engineering is good engineering with special areas of emphasis, …
  1. Top-down approach
  2. Life cycle orientation
  3. Better and more complete emphasis on definition of requirements
  4. Interdisciplinary approach"

Blanchard and Fabrycky, Systems engineering and Analysis, 2005

- Starts to define what is different – but **how achieved**?
- But Systems Engineering and Engineering are synonymous still
- Does this mean Engineers who aren't Systems Engineers are "bad"?

Working RR definition

The definition taught in Rolls-Royce Is

- *Systems Engineering is applying the concept of a system to a situation in order to gain insight and understanding (Systems Thinking), in a systematic and repeatable manner (Systems Approach), to the realization of a new system or the modification of an existing one.*
- *Where a system is an assembly of components (technologies, people, information, etc.), connected together in an organized way to form a whole, this whole showing properties of the whole, rather than properties of the components.*
- *A system has systemic properties and characteristics which we use to understand and make predictions about the problem or situation under investigation.*" From one week training course used in Rolls-Royce – provided by Stuart Burge (of BurgeHughesWalsh)

Defines what makes Systems engineering different,

Gives focus for training

Applies at any level in solution, different to "Engineering a system"

Skill and process views

Two views of how to do SE can emerge

- **SE = Process** – individuals must know what to do – and then if you do the Systems Engineering success will come.
- **SE = the skill of Systems Thinking** –get the right skills into organisation roles – the right thinking will create better solutions

At INCOSE IS in Chicago 2010 there were sound papers focusing on **each** specific approach

Balance skill and process

Being Systematic	**Good process**	**No invention / rework** No real thinking, Systems process methods "by the numbers" methods, 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** Individuals "uninterested" in process –no control, critical things missed, reinvention, some "mavericks"
		Poor Systems Skills	**Good Systems Skills**
		Being Systemic	

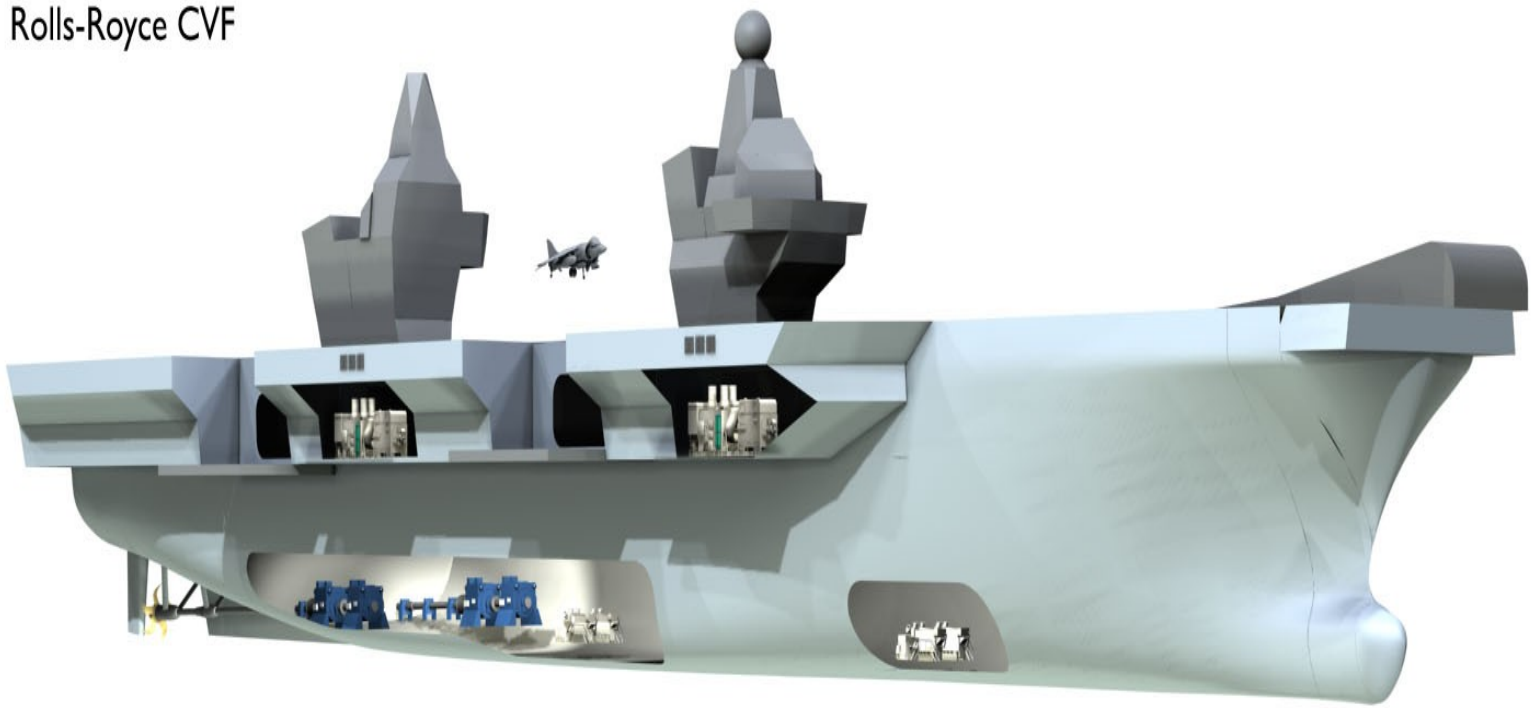
Trading

- Avoid sub-optimisation – don't "make the best parts rather than best system"
- This is explicit in NASA definition of Systems Engineering

[Systems Engineering is] "creation of alternative system design concepts, performance of design trades, selection and implementation of the best design"

NASA – Systems engineering handbook

Queen Elizabeth class Aircraft carrier – power supply



Factors affecting System selection

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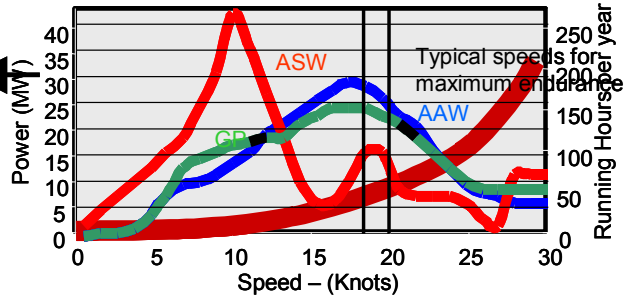
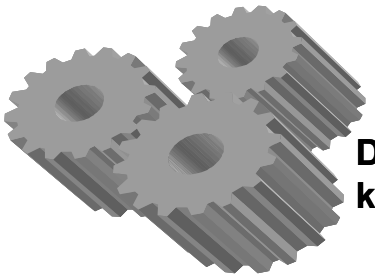
Requirements

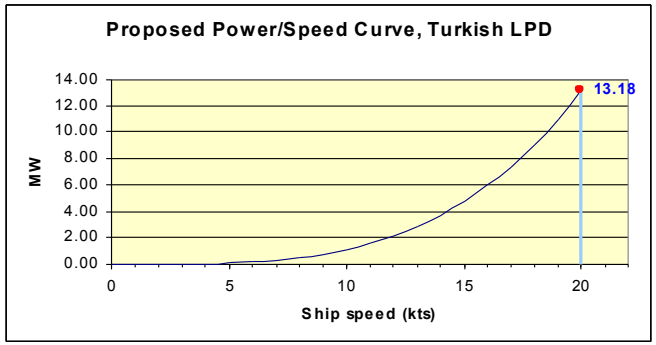
Electrical load chart

Domain knowledge

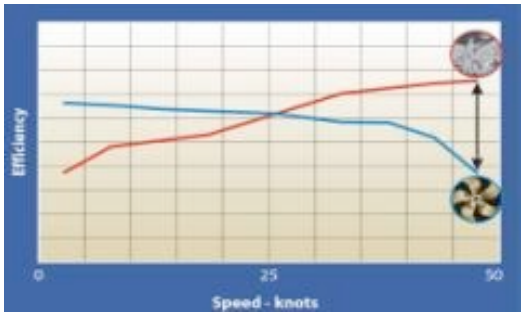
Operating profile(s)







Equipment characteristics



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

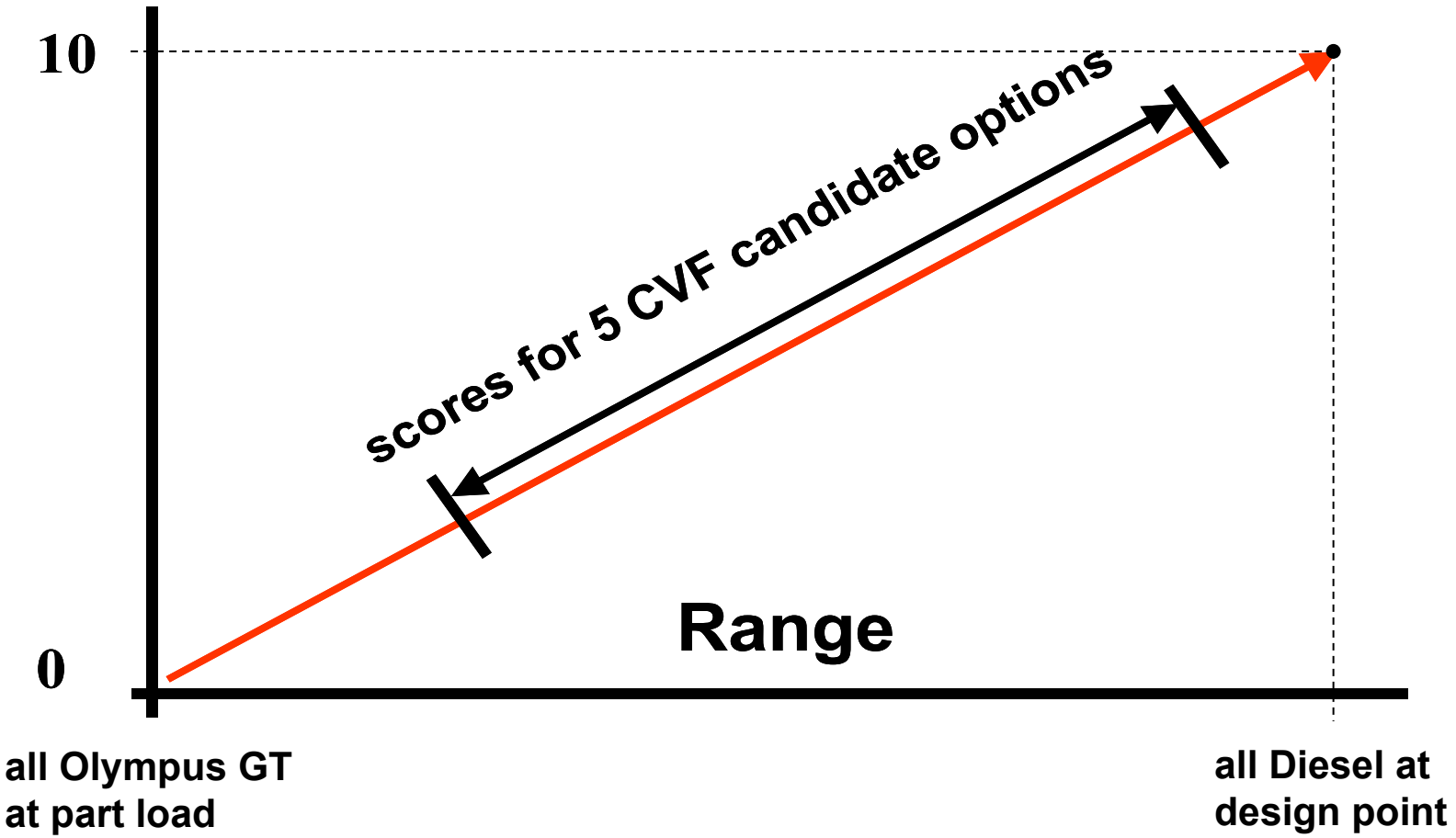
This prime mover selection then reviewed using an independent tool – same decision reached

Weighted attributes

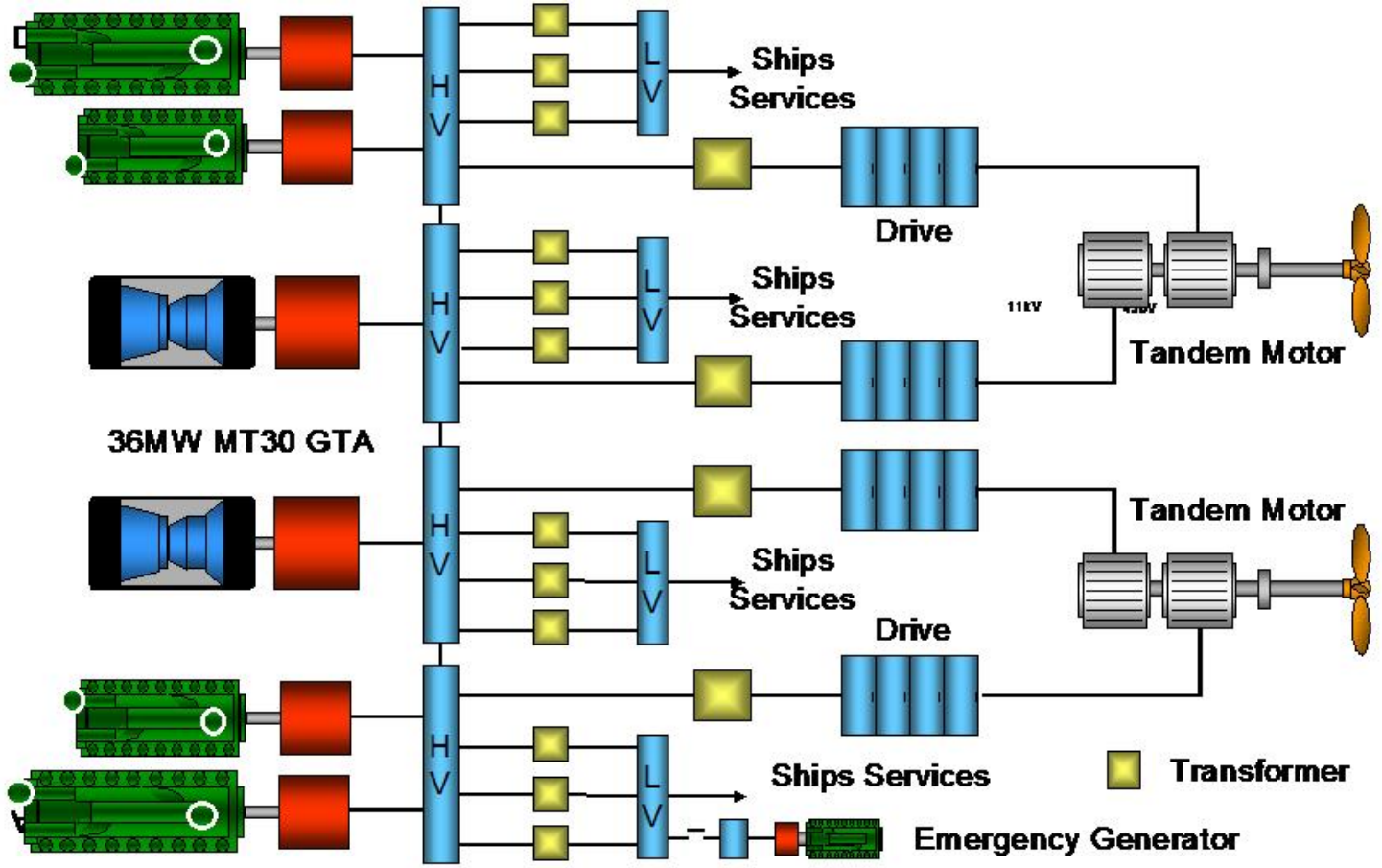
- In conjunction with stakeholders key assessment criteria were developed
- These were compared pair wise in weighted scale
  - A>>>> B = 8
  - A>>> B = 6
  - A>>B = 4
  - A > B = 2
  - A = B = 1
  - A< B = 0.25
  - etc

	Weighting
UPC	1.000
installed power, EOL	0.848
Tech Readiness	0.802
HV Design	0.526
Maintenance cost	0.371
Fuel cost	0.319
range	0.313
Footprint	0.293
Supportability	0.284
Re-Configurability	0.279
Redundancy	0.119
Generating capacity margin	0.105
Navalisation	0.074

Scoring based on viable maxima and minima



The winning system



Schematic of QE Class aircraft carrier power and propulsion system

Major Combatants – Power and Propulsion

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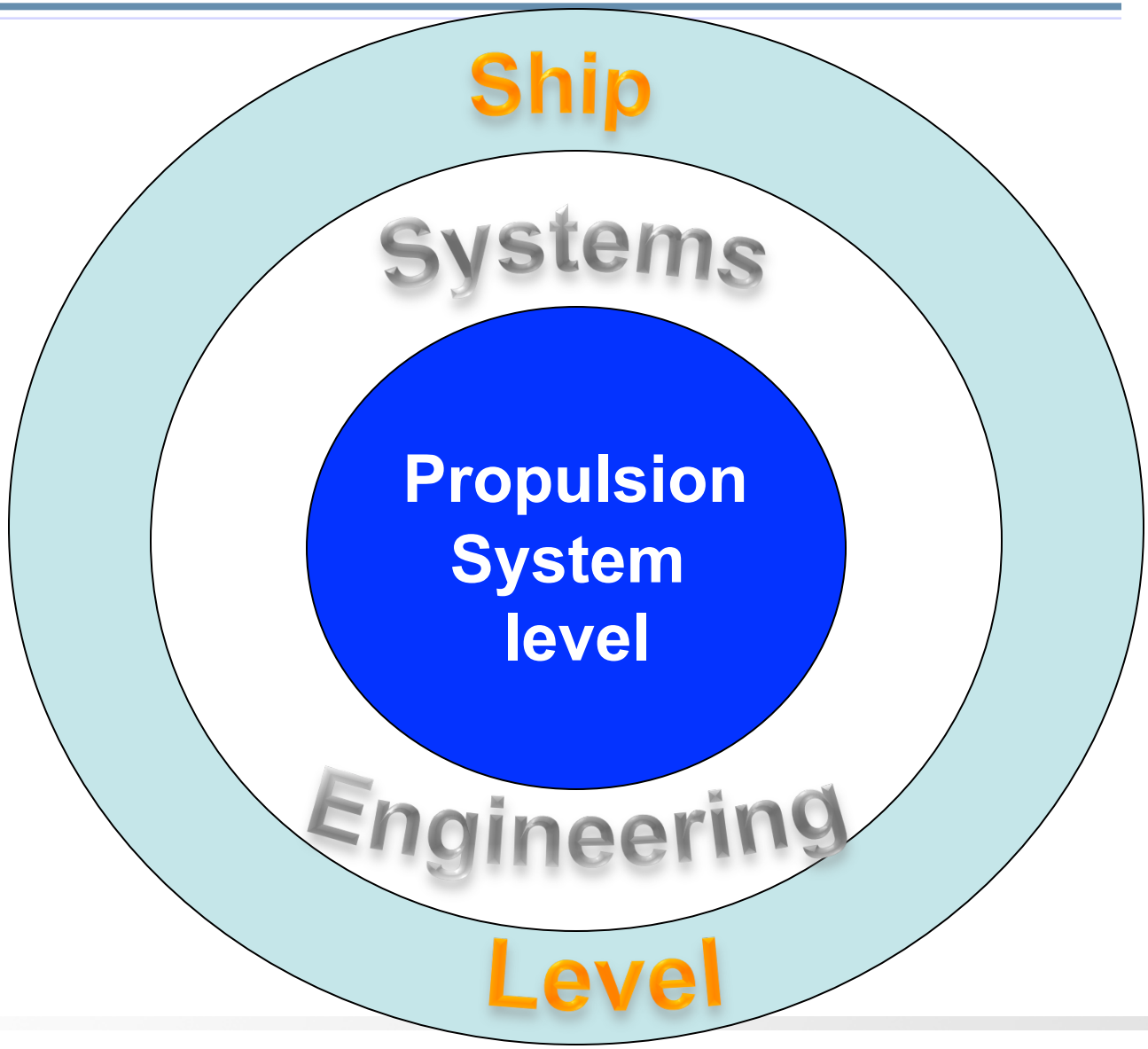
Queen Elizabeth Class

LCS USS Freedom

DDG1000

Summary – Working between layers



Other aspects of trading

There are other aspects of trading that can be considered

1. **Between requirements and solution**
   - Use potential solutions to better understand requirements
2. **Between levels in a solution**
   - Systems made up of sub-systems – so blend of “top-down” and “bottom-up” needed
3. **When to do things**
   1. Value of information changes with **when** in the lifecycle the information becomes available
   2. So trade effort to produce information with **value or impact** of information

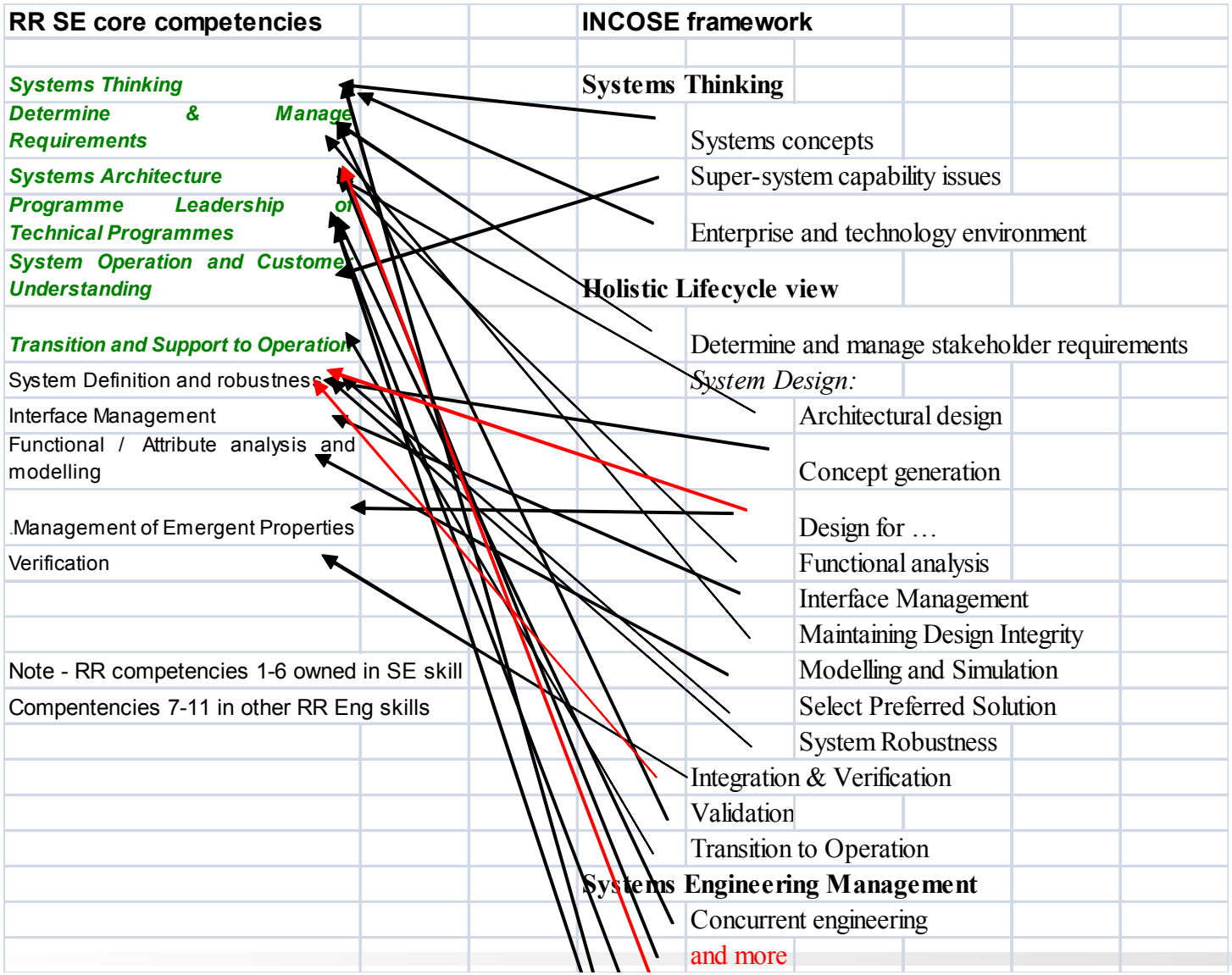
Tailoring

Tailor – "**to** fashion or **adapt to a particular** taste, **purpose** need, etc."

Tailoring SE competence definition

- Define competencies / roles for Systems Engineering
- Where to start?
  - “12 Systems Engineering roles” – Sarah Sheard 1999
  - INCOSE competency framework and guide to evaluation
- Complication
  - There are 23 other engineering skills in RR.
- Approach
  - Translate competency to match exiting RR terminology
  - Define specific Systems engineering roles
  - Place Systems Engineering competencies in other engineering role definitions

Tailoring of competency framework



Defining Roles

Two types of Systems Engineer role defined

- **Project Systems Engineer** – a lead for enabling Systems thinking in project teams
- **Work Package Owner** - key programme leadership of technical programmes – interface with PM roles

and

Defining appropriate levels of Systems Engineering competencies in rest of RR engineering roles

Others forms of tailoring

1. Tools use

- Tailor tool use by asking “What do I want from tool use?”
- “*A fool with a tool is a more dangerous fool*”

2. Tailor process

- **Rigid application of / or over-specific process is of limited use**
- See, for example, work by
  - Eric Honour on ROI from SE
  - Andy Pickard on Technical Risk (Chicago 2010)
  - Pickard and Nolan on Tailoring process (this conference)
  - Holt and Beasley on new technology system readiness (this conference)

(Systems) Thinking

Systems Thinking

- Systems Thinking differentiates Systems Engineering from traditional engineering (or reductionist thinking)
- It is to balance process (systematic) and reductionist approach – **not replace**
- It gives structure to understanding problem - be it
  - Product
  - Service

  Or
  - roles, skills, processes and operations of the organisations / enterprises that define / produce them

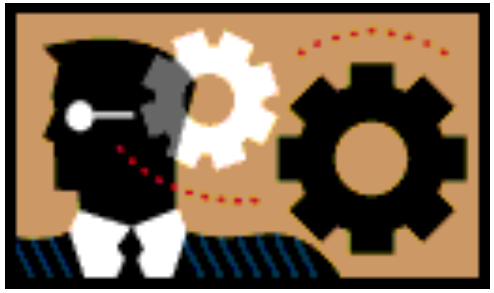
Systems Thinkers

Lateral Thinkers

End Game

Mediators

Don't treat a problem where it is found



Optimise parts does not optimise whole

Integrate between levels

Simplify Complexity

Inquisitive into the whole

See details in context of the whole

Slide adapted from presentation to Bristol University 24 May 2011 by **Dr Jon Elphick** from **Atkins**

Applying / implementing Systems engineering

- Systems Engineering is not a “solo” sport
- So the role of the Systems Engineering function in Rolls-Royce is
  - “***to make Systems Engineering the way Rolls-Royce does Engineering***”
  - Project Systems Engineers cannot do Systems Thinking on their own
- It is disappointing the SE handbook (admittedly sub-titled “A Guide for System Lifecycle Processes and Activities”) makes no mention of Systems Thinking in the index.

Conclusions

Conclusions

- Need focus on **Systems Thinking** to explicitly develop this specific, and difficult skill
- Must **balance** process / skill / tools
- **Trading** is vitally important to avoid sub - optimisation, and implies iteration.
- Further guidance on how to **tailor** the level and type of Systems Engineering given the situation is needed.
- Systems Engineering and Thinking should be applied not only to the systems that are defined, but to the tools, processes and organizations that produce them.

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QUESTIONS?

Reliability, integrity, innovation