Would the real systems engineer please stand up?

Duncan Kemp & Jennifer Mollett

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Overview

- Background and Introduction to "The Problem"
- Overview of Systems Engineering "Types"
- The Framework and Types
- Relationships between Types
- A Review of Key Competencies
- Conclusions and Summary

The authors

Duncan Kemp

- 25 years systems engineering experience across defence, aerospace and IT domains
- Currently systems engineer for Rail in UK Department for Transport
- Previous roles include
  - MOD acquisition reform
  - MOD's C4 architect
  - Developing MOD's first SoS safety case
  - Submarine combat systems integration
  - Air Defence command and control

Jennifer Mollett

- 6 years systems engineering experience across land and naval sectors
- Previous roles include
  - Project Manager for BAE Systems' Systems Engineering for TLCM Working Group
  - Land Sector Lead for TLCM for BAE Systems' Strategic Capability Solutions
  - Technical Lead for statistical modelling on the environmental risk of acoustic activities

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Introduction

- Have you ever experienced the following?
  - "What you do is interesting, but it's not Systems Engineering."
  - "That's business strategy, why do we need complex mathematics?"
  - "Wow…that must be a really big project. How many people do you have working for you?"
- If so…join the club! And we're not alone…

Hitchins' Five Layer Model

Checkland's SSM

Ring Value Chain

Daw – 4 Level Trade-off Model

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* Plain Old Systems Engineering

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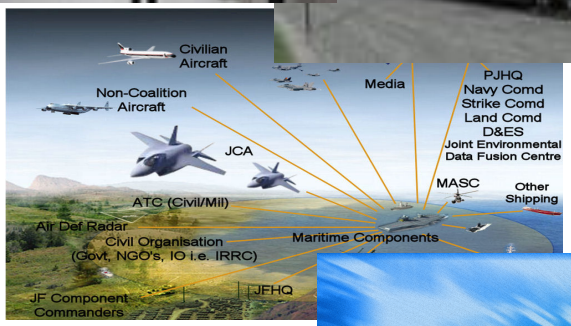
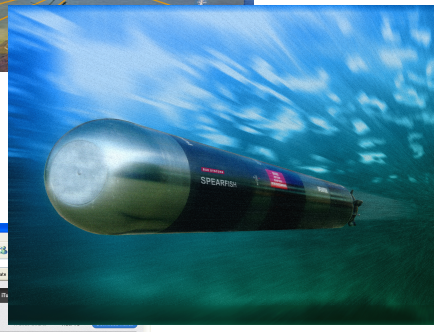
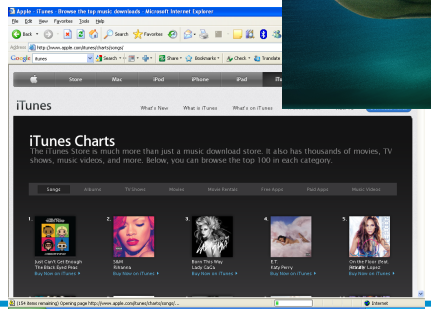
4 Types of Systems Engineering

- **Enterprise** – redesign of organisations to improve operational performance and/or reduce cost
- **Capability** – identifying, developing and integrating systems and services to realise operational capability
- **Product** - delivery of a set of integrated systems and subsystems to deliver operational performance
- **Service** – integrating existing and newly delivered systems to deliver operational services







Analysis Framework

- **Based on the Z1 Framework - "Six Steps to Success"**
- **Additional Step – "Define the high level architecture"**

Process Step	*Input*	*Key Question*	*Output*
Understand the Problem			
Investigate Alternatives			
Define the high level architecture			
Agree and Manage Requirements			
Agree and manage the interfaces			
Prepare the test and support systems			
Track progress against a plan			

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Historical Example

- Summer of 1940 and the dominance of the Wehrmacht and Luftwaffe
- Germany was ready to claim its next scalp…but they hadn't banked on…
- **Home Advantage** – The RAF were fighting over home territory and when shot down were able to recuperate and be back fighting within hours.
- **Underprepared Opposition** – The strategic bombing role was something the Luftwaffe hadn't prepared for. Wrong aircraft, inadequate logistics and "individualistic" ethos.
- **The Secret Weapon** – The RAF had an integrated air defence system, enabling fighters to be in the right place at the right time…again and again

Capability Engineering

Understand the Problem	**Understand the capabilities to be delivered, the current and future shortfalls and the associated risks**
Investigate Alternatives	**Consideration of options on how to "fill" the capability gap including how they align with expectations**
Define the high level architecture	**Articulation of the Systems of Systems that will meet the Capability need**
Agree and Manage Requirements	**Capture of Measures of Effectiveness for the Capability outcome – based on stakeholder expectations and acceptable risk levels**
Agree and manage the interfaces	**Capture of implicit and explicit relationships between components both intra and inter-Capability**
Prepare the test and support systems	**Consideration of operational scenarios against which the Capability is expected to deliver**
Track progress against a plan	**Development activities for those components that will deliver the Capability**

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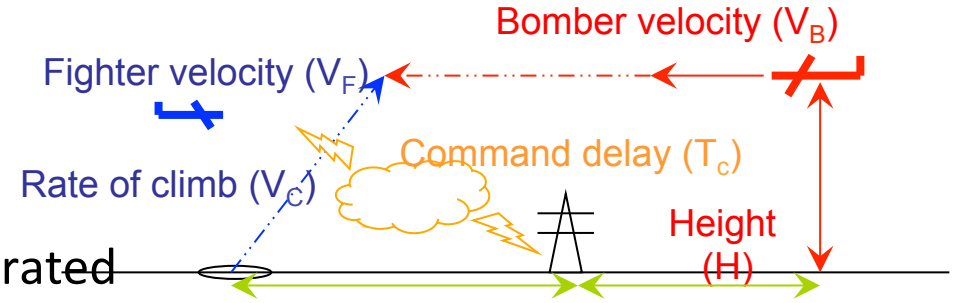
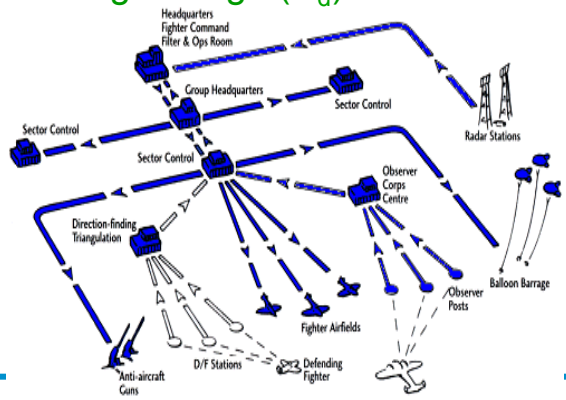
Capability Engineering Example

- Air Defence Capability delivered through a number of assets
  - Sensors
  - Decision Makers
  - Communications
  - Weapons Systems

"We can't use radio waves to destroy German Aircraft – but we can use them to detect them at range – would that be useful?" James Watson-Watt





- New and emerging technology integrated into existing baseline to provide better outcomes and move to "defensive warfare capability"

- Early insight of the benefits of emerging technologies in the role of Air Defence

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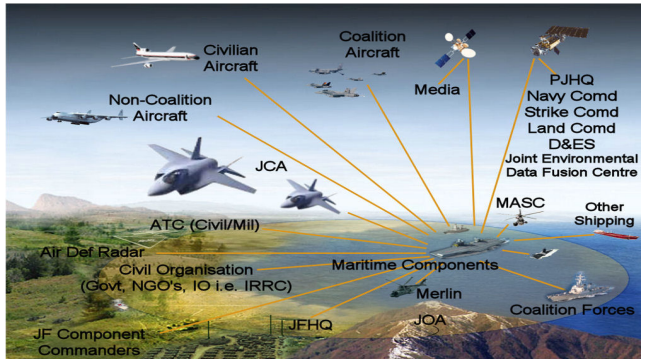
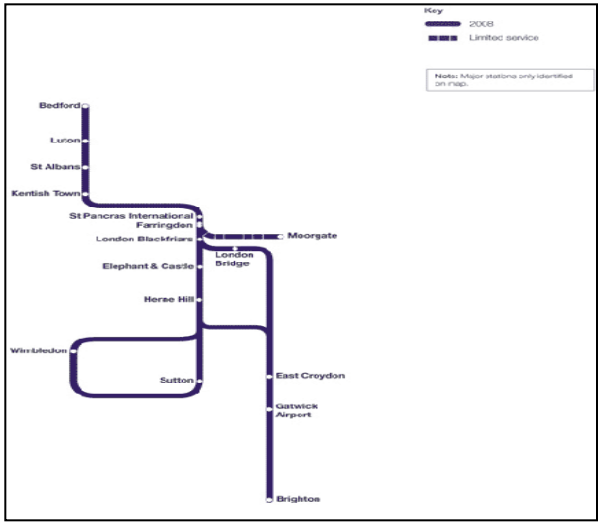
Capability SE some more modern examples

- Carrier strike
  - Capability delivered through multiple assets – air/sea/land
  - New "novel" operations in comparison to existing CVS
  - Integration with legacy/future assets
  - Coordination of LoDs





- Thameslink upgrade
  - New rolling stock
  - In-cab signalling and automatic train operation
  - New stations and infrastructure
  - New timetables
  - Trained drivers and dispatchers
- All to deliver 50K more passengers an hour in the peak – through old Victorian tunnels

Product Engineering

Understand the Problem	**Statement of the performance characteristics that are required to meet the operational need**
Investigate Alternatives	**Consideration of functional options with associated performance, cost and risk**
Define the high level architecture	**Capture of the how the different "parts" of the product combine to produce the desired effect**
Agree and Manage Requirements	**Articulation of key performance levels at system and subsystem levels**
Agree and manage the interfaces	**Capture of intra and inter product interfaces and the contribution of the product to the wider system effectiveness**
Prepare the test and support systems	**Validation of the product performance against specified scenarios and confirmation of its contribution to the higher level service or capability**
Track progress against a plan	**Capture of engineering tasks to develop and integrate components within the required timescales**

Product Engineering Example

- Key to the success of the Battle of Britain were products such as Spitfires and Chain Home radars
- Both were developed using processes akin to modern "Systems Engineering"
  - Requirements based on mix between technology, intelligence and operational research
  - Iterative development enabling regular updates based on operational feedback and emerging technologies
- However, without each other, their operational effectiveness was limited

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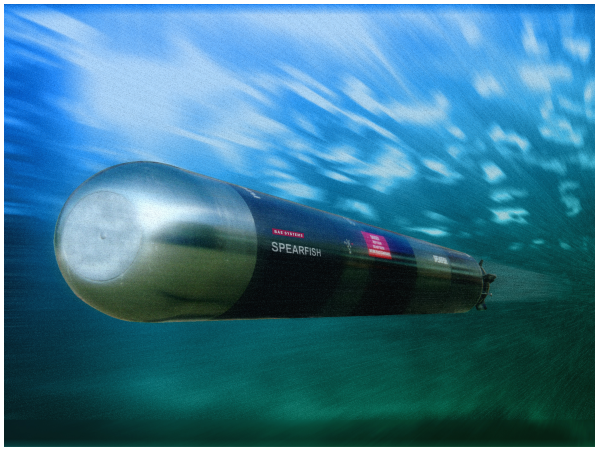
Product SE some more modern examples

- Spearfish
  - Designed to work in many challenging environments
  - Designed as countermeasure for submarine threats
  - Multiple deployment techniques



- Tilting train designed to work with existing rail infrastructure
- Complies with existing standards
- Complex system in its own right
- Carries 450 people at up to 125 mph
- 6000-7000 people per hour per track

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Service Engineering

Understand the Problem	**Articulation of the levels of effectiveness required of the service**
Investigate Alternatives	**Consideration of the best means to deliver the service to the end customer using current, or soon to be introduced, assets**
Define the high level architecture	**Capture of how the technical service will meet the end customer's needs**
Agree and Manage Requirements	**Measures of Performance for the service and key components in main and fallback modes**
Agree and manage the interfaces	**Capture of the related components that are required to deliver the service**
Prepare the test and support systems	**Consideration of the "level of confidence" required to ensure that the service will deliver as expected**
Track progress against a plan	**Capture of the development activities and ordering to meet delivery timescales**

Service Engineering Example

- Key Air Defence Capability information services
  - Raid Tracking – where have they been and where will they go next?
  - Command and Control – directing own forces to engagement
- Services were designed and optimised against a number of performance criteria
  - Frequency
  - Timeliness
  - Level of Detail
- Iterative Development of Services to harness the benefits of new and emerging technologies whilst ensuring service robustness and resilience

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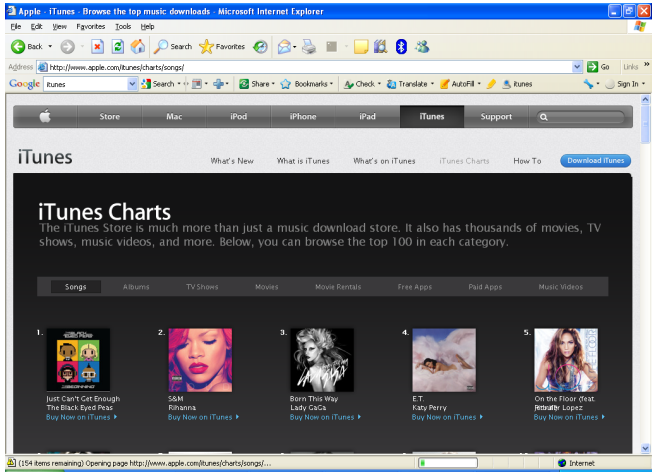
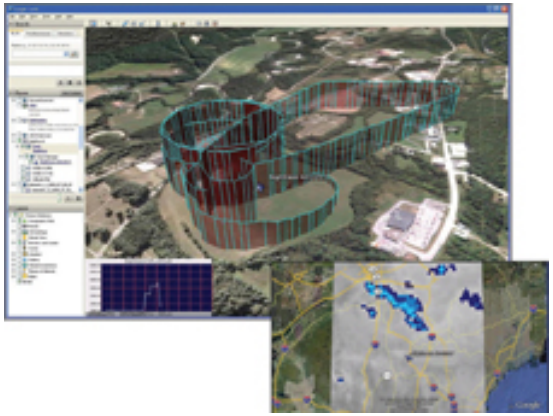
Service SE some more modern examples

- iTunes / iPOD
  - Service delivery evolution from domestic internet connection through to third generation mobile networks
  - Evolution of compatible devices from iPod through to iPhone and iPad
  - Service fundamentals have remained the same





- Joint operational picture
  - Situational Awareness to support strategic and operational decision making
  - Information centric model with multiple providers and users
  - Level of detail appropriate to decision

Enterprise Engineering

Understand the Problem	**Expression of the Problem and its impact on the Enterprise Objectives**
Investigate Alternatives	**Consideration of options to address problem**
Define the high level architecture	**Articulation of how the solution will address the problem and show benefit against the Enterprise Goals**
Agree and Manage Requirements	**Capture of "what good looks like", associated performance characteristics and where the solution will impact and benefit**
Agree and manage the interfaces	**Capture of the "change" elements and the impact of the solution on their outputs**
Prepare the test and support systems	**Articulation of the deployment options and the capture mechanisms that will be applied to measure the effectiveness of the solution**
Track progress against a plan	**Activities and timescales to deliver the benefit within the required timescale**

Enterprise Engineering Example

- Deployment of the "Secret Weapon" (Integrated Air Defence System) was delivered by a whole new organisation
- Introduction of roles such as:
  - Radar Operators
  - Radar Trackers
  - Fighter Controllers
- Sharing of roles within a wider network enabling centralised command and control and *removal* of some squadron authority
- The pilot could now concentrate on doing what he did best … fighting the Luftwaffe!

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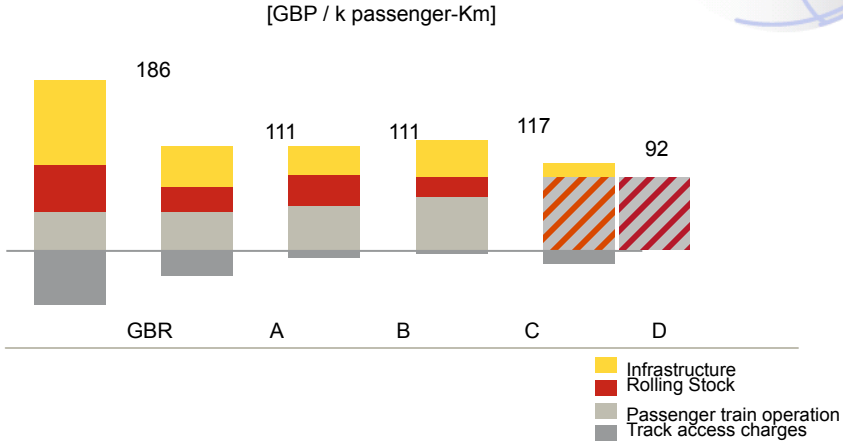
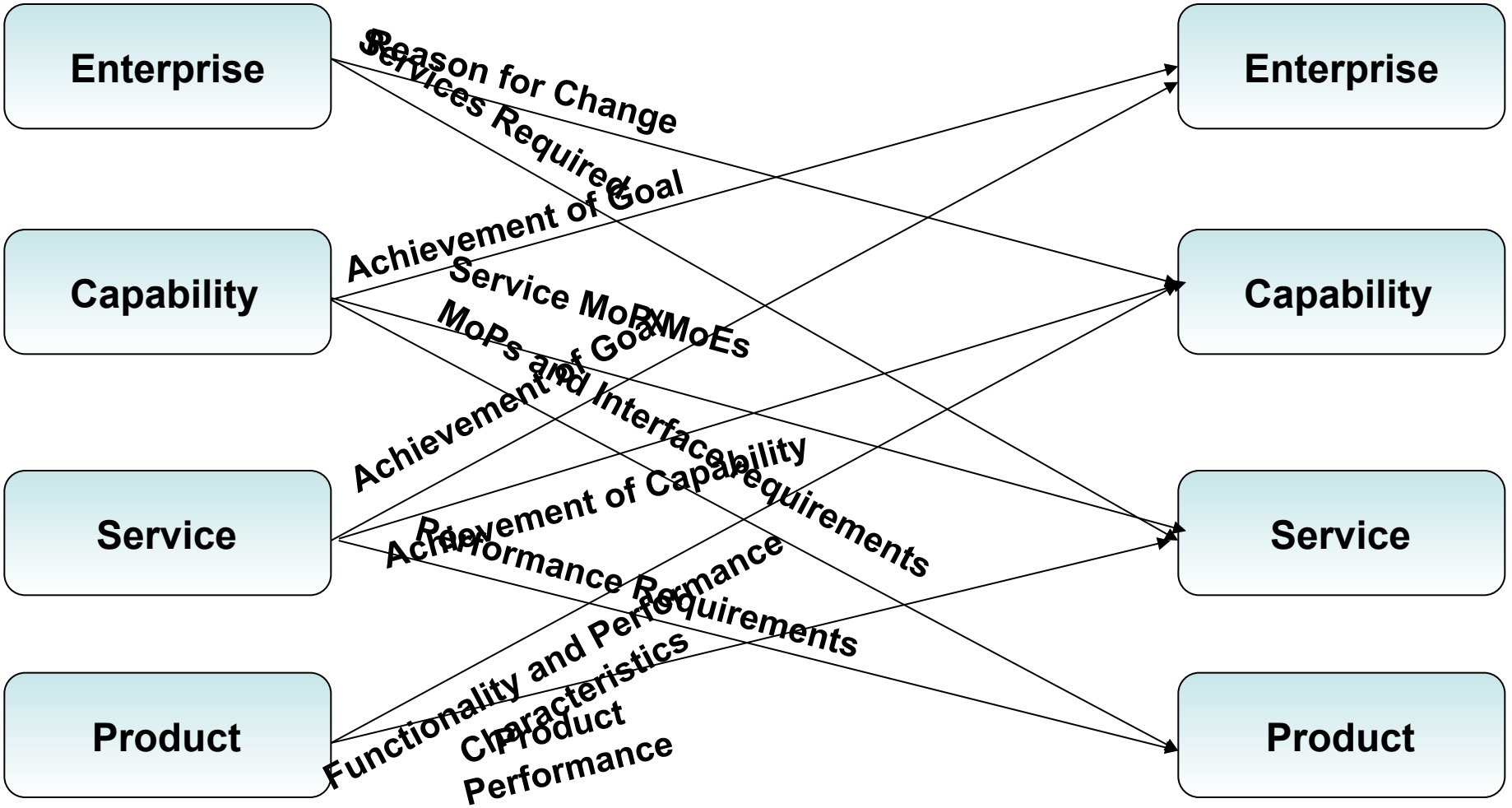
Enterprise SE some more modern examples …

- Rail value for money study
  - What legal, operational and cultural barriers stand in the way of efficiency improvements?
  - Align the incentives across different parts of the rail industry to generate greater efficiency?
  - Identify the role of new technology, processes and working practices in fostering greater efficiency?
  - Identify ways of generating more revenue?



- Climate change
  - Cross-cultural and political challenges due to the need for multi-nation collaboration
  - Balancing the needs for economic/ industrial growth against the need to minimise carbon footprint

Relationship between the 4 Types

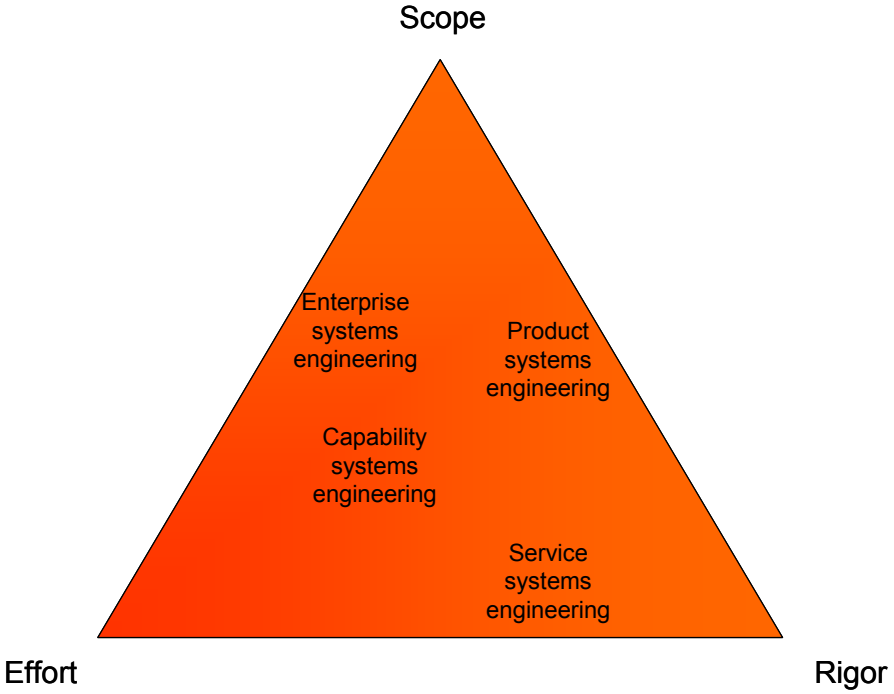


People

Existing Systems Engineering Competencies still apply as it is the same 7 steps

Increased focus on

- **Systems thinking** –critical thinking, multiple perspectives, interrelationships
- **Coping with ambiguity** – adopting to shifting baselines dealing with undefined dependencies
- **Tailoring of the process** –knowing when to change, balancing whole life whole systems rigor and persuasion and influencing
- **Varying scope-rigor-effort** – recognising which factor lead and how to delivering a balanced solution
- **Persuasion and influencing** – agreeing involvement, agreeing need for rigorous approach, agreeing best approach and results
- **Adapting and innovating** –knowing when to adapt today's solution and when a fundamental change is required, knowing how to adapt and innovate



Conclusions and Summary

- Four different "types" of Systems Engineering
  - Enterprise
  - Capability
  - Service
  - Product
- Adaptation of Z1 "Six Steps to Success" to articulate the differences between the different types
- Operating in Enterprise, Capability and Service may require more focus on specific Systems Engineering Competencies than traditional product Systems Engineering
- More work is required to develop supporting guidance, pull-through of best practice etc

Would the real systems engineer please stand up?

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