

“Suits you sir! – choosing the right style of SE before tailoring to fit”

**Using Functional Failure Modes and
Effects Analysis to guide selection
of the right Systems approach**

The authors



Copyright © 2015 Rolls-Royce plc and Crown Copyright. Published and used by INCOSE with permission. This paper represents the views of the authors, and does not represent the position of either Rolls-Royce or the MOD



Rolls-Royce

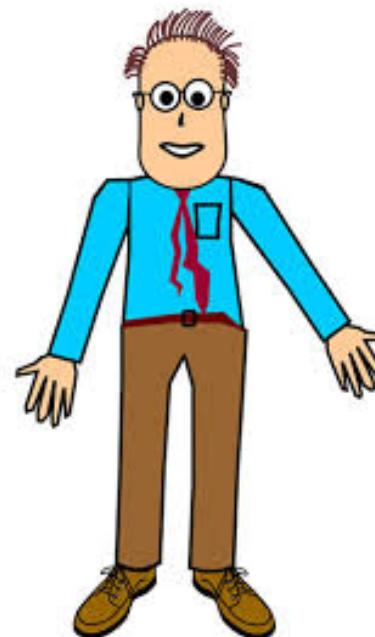
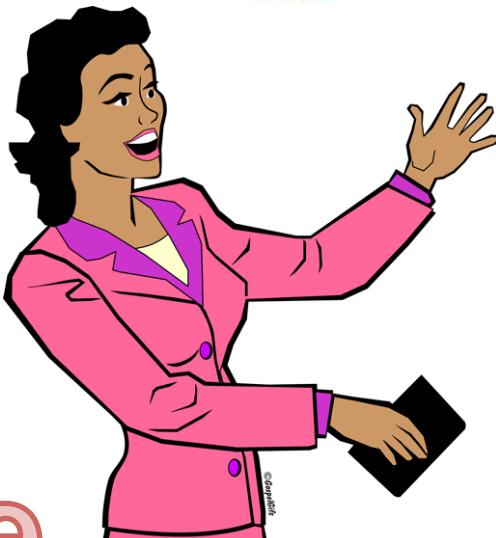
25th anniversary
annual INCOSE
international symposium
Seattle, WA
July 13 - 16, 2015

Introduction

Alice



Bob

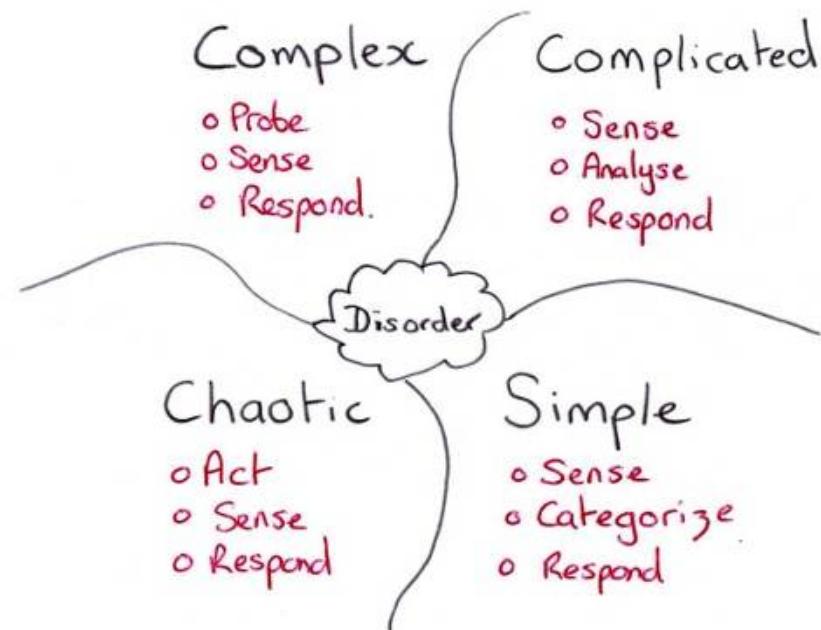


Dave

Charlie

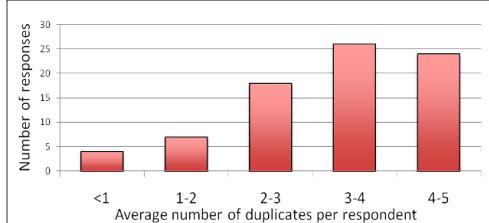
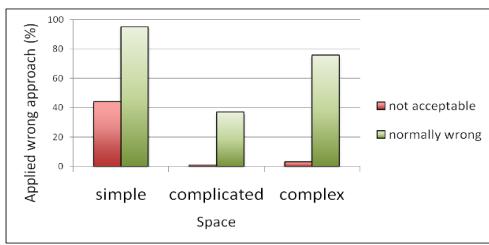
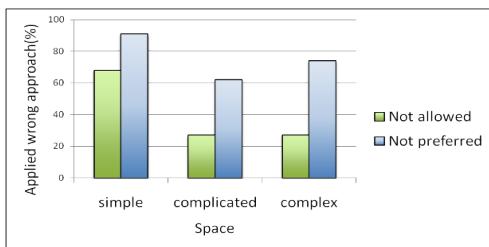
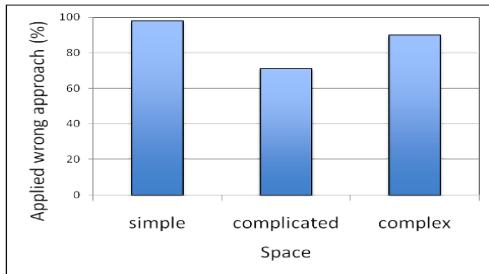
25th anniversary
annual INCOSE
international symposium
Seattle, WA
July 13 - 16, 2015

Cynefin Framework



- Decision making framework developed by Professor David Snowdon
- 'Most influential HBR paper' in 2007
- Used by US/UK/EU Governments.
- Aids managers and leaders to understand which context they are operating in.
- Many organisations operate across all 4 of the contexts.

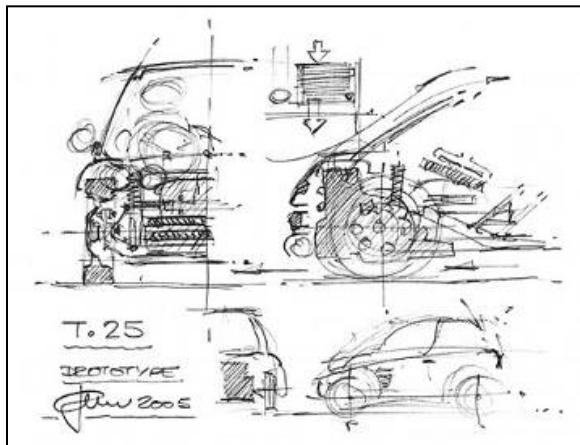
2014 paper findings



1. Project professionals *do not* use the right approach for the space they are in
2. Organisations let good practice happen, *but don't make it happen*
3. Project professionals are guided by what they believe is *normally* right and wrong
4. Project professionals do not understand that *different spaces required different approaches*

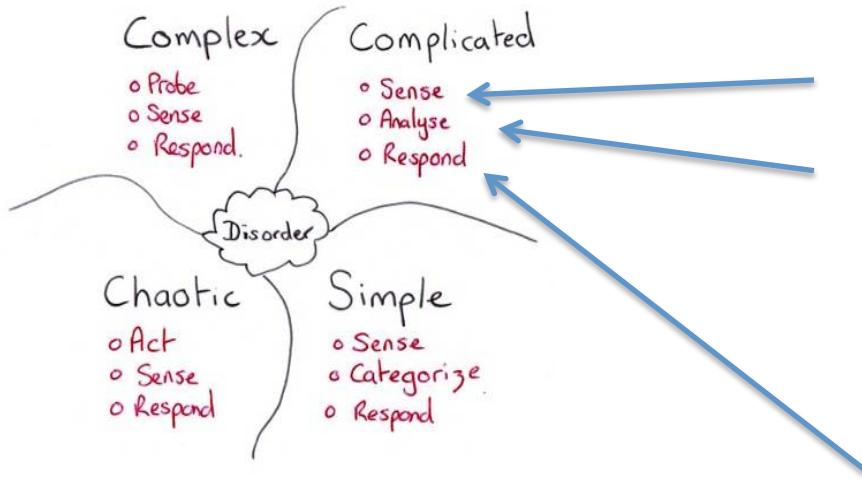
So what?

Systems engineering is adding cost, complexity and delays where it is inappropriate



Systems engineering is not being applied where it can add value

So what did we do ...



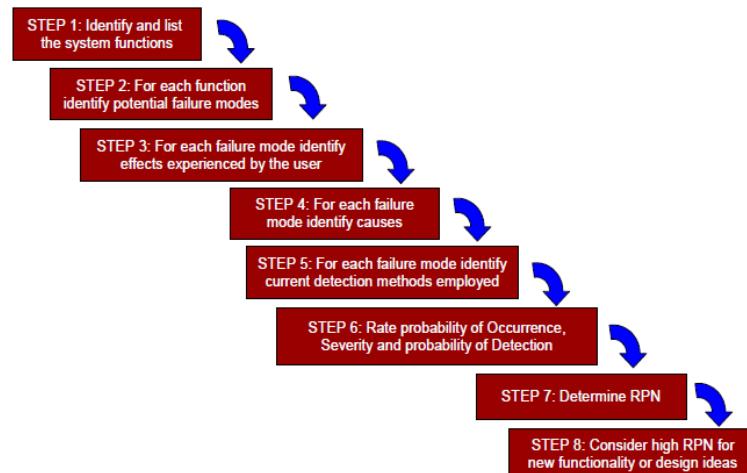
SE is failing to select the right approach

How do I analyse failures?

Lets do a functional failure mode analysis

And develop detection and mitigation measures

And then deploy them in our organisations

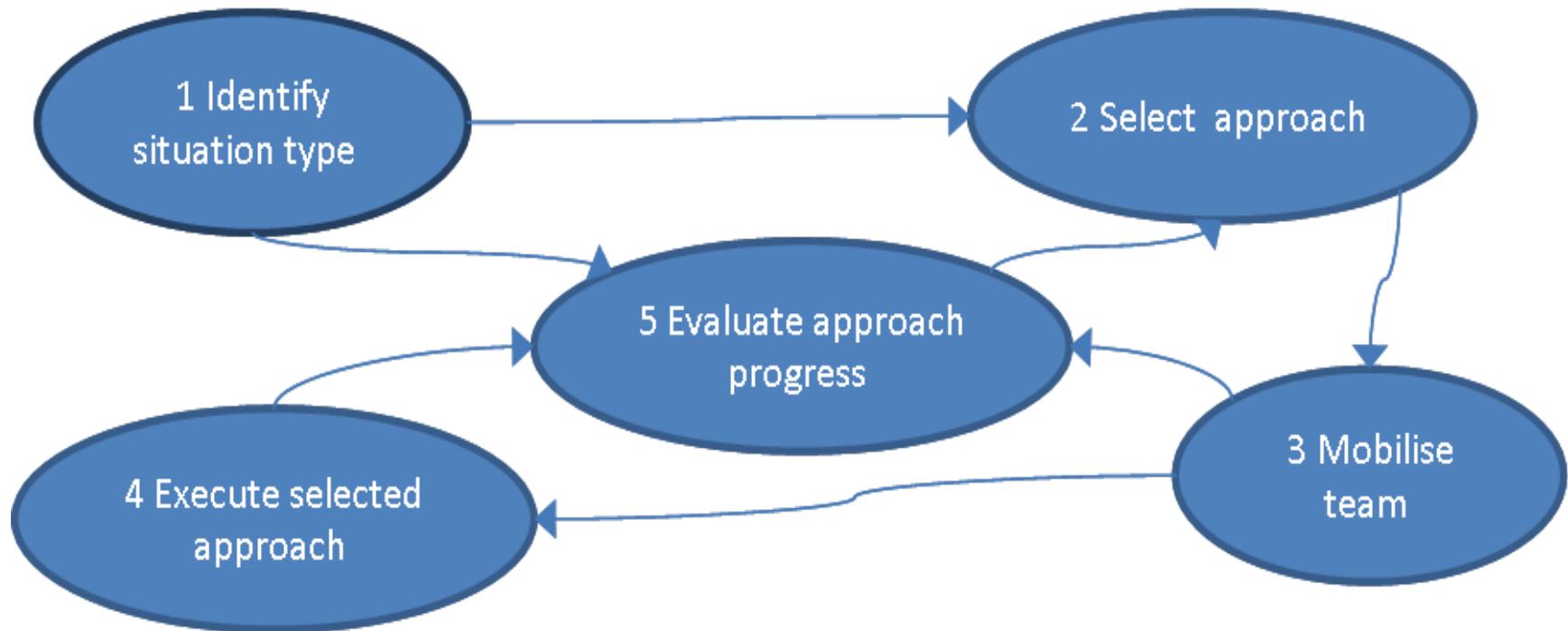


Usual suspects

- Too much
- Too little
- No
- Intermittent
- Unintended application

Failure Modes		Functional FMEA			Design Suggestions/Comments	
Failure Modes		Failure Modes			Design Suggestions/Comments	
Function	Functional Failure Mode	Effects	Causes	Detection	RPN	Design Suggestions/Comments
LOAD DIRTY CLOTHES	No Load	No wash	3 User Error	2 None - but required for user to load clothes	9 54	Include load cell or other sensor for load detection. If no load detected, do not start wash cycle. If load detected, start wash cycle.
	Over Load	Very poor wash	5 User Error	2 None - but required for user to load clothes	9 270	Include load cell or other sensor for load detection. If over load detected, do not start wash cycle. If load detected, start wash cycle.
	Under Load	Poor Wash	4 User Error	4 None - but required for user to load clothes	9 144	Include load cell or other sensor for load detection. If under load detected, do not start wash cycle. If load detected, start wash cycle.
	Intermittent Load (includes extreme mix of loads)	Colour run	6 Items shaded	6 None - but required for user to load clothes	9 486	Line of sight sensor will not detect this situation and therefore system will start wash cycle. If wash cycle starts, include load cell or other sensor for load detection. If load detected, stop wash cycle.
	(Unintended) Load (pot object in items)	Fabric Shrink	2 by others	9 None - but required for user to load clothes	9 567	Line of sight sensor will not detect this situation and therefore system will start wash cycle. If wash cycle starts, include load cell or other sensor for load detection. If load detected, stop wash cycle.
		Injury/death of user	8 User Error	2 None	10 160	Costs include a fast stop button that overrides any interlocks
		Object damage machine	7 User Error	3 None	10 210	
		Object damage	8 User Error	2 None	10 160	

Solution space selection functions



FFM Workshops & Data

- Output from workshops....
- For each function in the stage 1 tailoring model
- Against each of Burge's 5 usual suspects
- Over 20 pages of analysis captured.

Functional FMEA									
System: Washing Machine		O - probability of Occurrence	1: Very rare > 10: Frequent		Date: 1/1/01		No 123		
Subsystem:		S - Severity of occurrence	1: No Effect - 10: Most Severe		Author: S. Powder		Issue 1		
Element:		D - probability of Detection	1: Certain to Detect - 10: Cannot Detect		Checked: A. Spinner				
Function	Functional Failure Mode	Effects	S	Causes	O	Detection		Design Suggestions/Comments	
						Current Employed Method	D	RPN	
LOAD DIRTY CLOTHES	No Load	No wash	3	User Error	2	None - but requirement for weigh load function identified	9	54	Include load cell or other sensor for load detection
	Over Load	Very poor wash	5	User Error	6	None - but requirement for weigh load function identified	9	270	Include load cell or other sensor for load detection - will need to guard against wet towels or similar giving false-positive type signals
	Under Load	Poor Wash	4	User Error	4	None - but requirement for weigh load function identified	9	144	Include load cell or other sensor for load detection
	Intermittent Load (Hidden extreme mix of load)	Colour run	6	Items shielded by others	9	None - but functionality required for detecting mixed loads	9	486	Line of sight sensing will not detect this situation and therefore system solution should attempt to avert this
	Unintended Load (pet object in items)	Fabric Shrink	7	Items shielded by others	9	None - but functionality required for detecting mixed loads	9	567	
	Injury/death of pet	Injury/death of pet	8	User Error	2	None	10	160	Could include a fast stop button that overrides any interlocks
		Object damages items	7	User error	3	None	10	210	
	Object damages machine	Object damages machine	8	User Error	2	None	10	160	

Mode	Effects	Causes	Detection	Intervention
Substantive Inappropriate Only pick one approach	Substantive Only pick one approach	Organizational friction on inter-case effect	Check for evidence of linear and linear programs	Provide Training and Education to build SDF Understanding of underlying Assumptions and procedures mapping Case type assessment
Multiple Inappropriate Only pick one approach	Multiple Inappropriate Only pick one approach	Organizational friction on inter-case effect	Check for evidence of planned and planned programs Reflection - decoupled form planned programs	Provide Training and Education to build SDF Understanding of underlying Assumptions and procedures mapping Case type assessment
Multiple Inappropriate Only pick one approach	Multiple Inappropriate Only pick one approach	Organizational friction on inter-case effect	Check for evidence of linear and linear programs	Introduce Italian Flair approach to include measures of uncertainty so that they can be actively managed Provide 'Health' health report
Acquisition cycle Informed by political cycle	Acquisition cycle Informed by political cycle	Check for evidence of planned and planned programs Reflection - decoupled form planned programs	Check for evidence of planned and planned programs Reflection - decoupled form planned programs	Provide Training and Education to build SDF Understanding of underlying Assumptions and procedures mapping Case type assessment
Acquisition cycle Informed by political cycle	Acquisition cycle Informed by political cycle	Check for evidence of planned and planned programs Reflection - decoupled form planned programs	Check for evidence of planned and planned programs Reflection - decoupled form planned programs	Provide Training and Education to build SDF Understanding of underlying Assumptions and procedures mapping Case type assessment
Acquisition cycle Informed by political cycle	Acquisition cycle Informed by political cycle	Check for evidence of planned and planned programs Reflection - decoupled form planned programs	Check for evidence of planned and planned programs Reflection - decoupled form planned programs	Provide Training and Education to build SDF Understanding of underlying Assumptions and procedures mapping Case type assessment

Causes	Detection	Interventions
Emotions & sensations, like Shyness, are triggered significantly	Check/Mind one's understanding on approach to online text participation, and make use the 'help' section of the discussion Shyness, and the discussion Shyness (ASDQ, pg 33)	Assumptions and dependencies Risk assess people Introduce Italian Flag app to encourage them to contribute Introduce 'Virtual Health' app
Organisational culture does not promote behaviour that involves or 'tease' risk	Check for evidence of risk reduction, LFE activities and campaigns in the steering, and innovation, and leadership to innovation	LFE activities - reinforce Conduct more LFE, Leadership, and innovation activities Need good risk system Collaborating, Communicating
Time lag between decision and impact is great - so decisions are made before they have made to happen, and the time lag between success is greater than the time lag between a proposal and compound risk	Check for evidence of mitigating time lag between decision and progression of decision activities	LFE activities - reinforce Conduct more LFE, Leadership, and innovation activities Need good risk system Collaborating, Communicating
Inappropriate responses to risk measures of success on consciously perceived risk, and gives false sense of confidence	Contact 'cold' review panel; check for evidence of bad practice, and bad practice	Incentivise collaboration, LFE activities - reinforce Conduct more LFE & Leadership, and innovation activities Need good risk system Collaborating, Communicating
	Contact 'cold' review panel; check for evidence of bad practice, and bad practice	
	Turn hindsight into foresight	

Functional failure modes

F ID	F u n c t i o n a l F a i l u r e M o d e
F1	Budget, resources and culture drive approach
F2	Mobilise too slowly
F3	Assume all spaces are the same, or there is only one approach
F4	Too long to identify space
F5	Correctly identify space but unable to convince/explain to others
F6	Pick wrong boundary/scope
F7	Fail to notice situation has changed
F8	Paralysis by analysis
F9	Pick approach we are comfortable with
F10	Don't partition into different parts
F11	Pick latest trendy approach
F12	Fail to prepare for chaos

Mitigations for failure modes

MID	Category	Mitigation action	Activity
M1	Right People	Know the four spaces (team)	
M2		Know the approaches (management)	
M3		Know how to execute in the 4 spaces (stakeholders)	
M4	Right Process	To ensure space is identified before implementation starts	
M5		To execute in each of the four spaces	
M6		To be able to monitor and change space as necessary	
M7	Right Organisation	To have measures and targets that work in all spaces	
M8		To have people that are available quickly to start work in any space	
M9	Right Culture	People understand different spaces need different approaches	
M10		Stories and myths of right/wrong approaches in the 4 spaces to illustrate 'why we do things this way round here'	

Case Studies

		Approach taken to solve Problem			
Problem Space Characteristics	Simple	Complicated	Complex	Chaos	
	Simple	Success – tasks done quickly, efficiently and consistently. 	Inefficient – over use of process, generation of unwanted documentation and solution potentially over-engineered.	Inefficient – no economies of scale	Inefficient – no delegation, decision maker overwhelmed by detail. 
	Complicated	Unsuccessful outcome – as system inter-dependencies and emergence not managed 	Success – complicated interactions under-stood, emergence managed and large team coordinated 	Inefficient and possibly failure – as parallel approaches waste resources and subsequent phases engage in expensive rework. 	Highly inefficient and probably failure – inter-dependencies unlikely to be under-stood by decision maker
	Complex	Unsuccessful outcome – stakeholders will diverge, change path will be undirected 	Unsuccessful outcome – environment will change faster than the project can deliver. Project will continually restart. 	Success – tempo of delivery matches environmental change, emergent behaviour managed. 	Unsuccessful outcome – decision maker unable to sense changes in the environment quickly enough
	Chaos	Unsuccessful outcome – mechanistic approach unable to cope with unplanned situation. 	Unsuccessful outcome – time taken to understand the problem results in increased instability. Stakeholders 'vote with their feet'	Unsuccessful outcome – parallel approaches insufficiently coherent to stabilise the situation.	Success – situation stabilised.

Case Study – UK Financial Crisis

2008-2014

Collapse of US Sub prime market
destabilises UK banking industry.

Decision point - intervene?

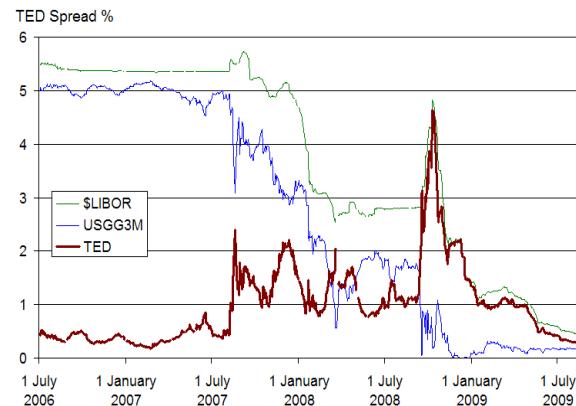
Oct 2008 UK government partially
nationalise UK banks.

£20bn buying 63% RBS

£17Bn buying 40% HBOS/Lloyds

2013 sell back of shares.

Parliamentary commission tighten
regulation and impose potential jail for
reckless banking



Case Study – UK Financial Crisis 1

F3. Assume all spaces are the same, or there is only one approach

Failure to understand that the financial system was a complex adaptive system. Instead it was treated as a simple system operating within a relatively unregulated market

F10. Don't partition into different parts

Failure to recognise the two different worldviews of the banking system: a business sector where failure was acceptable (indeed a healthy sign of a market operating) and an essential enabler to the wider economy.

F12. Fail to prepare for chaos

Systems approaches could have been used to understand the banking system, and in particular predict where changes to the system could make it less stable

		Approach taken to solve Problem			
		Simple	Complicated	Complex	Chaos
Problem Space Characteristics	Simple	Success – tasks done quickly, efficiently and consistently	Inefficient – over use of process, generation of unwanted, documented and isolates potentially over-engineered	Inefficient – economies of scale	Inefficient – no delegation, decision maker overwhelmed by detail
	Complicated	Unsuccessful outcome – as system interacts with environment and emergence not managed	Success – complicated interactions understood, emergence managed and large team coordinates	Inefficient and possibly failure – as parallel approaches waste resources and are not well integrated with subsequent phases	Highly inefficient and potentially failure – inter-dependent phases engage in expensive rework
	Complex	Unsuccessful outcome – stakeholders will diverge, change path will be undirected	Inefficient outcome – environment will change faster than the project can deliver. Project will continually restart	Success – tempo of delivery matched to environmental change, emergent behaviour managed	Unsuccessful outcome – decision maker unable to sense changes in the environment quickly enough
	Chaos	Unsuccessful outcome – mechanistic approach unable to cope with unplanned situation	Unsuccessful outcome – time taken to understand the situation results in increased instability. Stakeholders 'vote with their feet'	Unsuccessful outcome – parallel approaches insufficiently coherent to stabilise the situation	Success – situation stabilised
		R	S	W	FM



Case Study – UK Financial Crisis 2

M2. RIGHT PEOPLE - Know the approaches (management)

Recognition of the problem situation, and development of effective strategy.

M5. RIGHT PROCESS - To execute in each of the four spaces

Execution of “bailout” done decisively, following realization prompt action was needed, and more measured development of new banking controls

M8. RIGHT ORGANISATION - To have people that are available quickly to start work in any space

Rapid mobilization of people and resources for the bailout

M6. RIGHT PROCESS - To be able to monitor and change space as necessary.

After the crisis the development of a set of controls has followed the classic complicated design process

		Approach taken to solve Problem			
		Simple	Complicated	Complex	Chaos
Problem Space Characteristics	Simple	Success – tasks done quickly, efficiently and consistently	Inefficient – over use of process, generation of unwanted documents and isolates potentially over-engineered	Inefficient – economies of scale	Inefficient – no delegation, decision maker overwhelmed by detail
	Complicated	Unsuccessful outcome – as system interacts with environment and emergence not managed	Inefficient and possibly failure – as system interacts with environment and emergence not managed	Inefficient and possibly failure – as parallel approaches waste resources and are not well coordinated with subsequent phases	Highly inefficient and possibly failure – inter-dependencies likely to be understood by decision maker
	Complex	Unsuccessful outcome – stakeholders will diverge, change path will be undirected	Unsuccessful outcome – environment will change faster than the project can deliver. Project will continually restart	Successful – tempo of delivery matches environmental change, emergent behaviour managed	Unsuccessful outcome – decision maker unable to sense changes in the environment quickly enough
	Chaos	Unsuccessful outcome – mechanistic approach unable to cope with unplanned situation	Unsuccessful outcome – system taken to standstill as it results in increased instability. Stakeholders ‘vote with their feet’	Unsuccessful outcome – parallel approaches insufficiently coherent stabilise the situation	Success – situation stabilised



Case Study – UK Foot & Mouth

2001

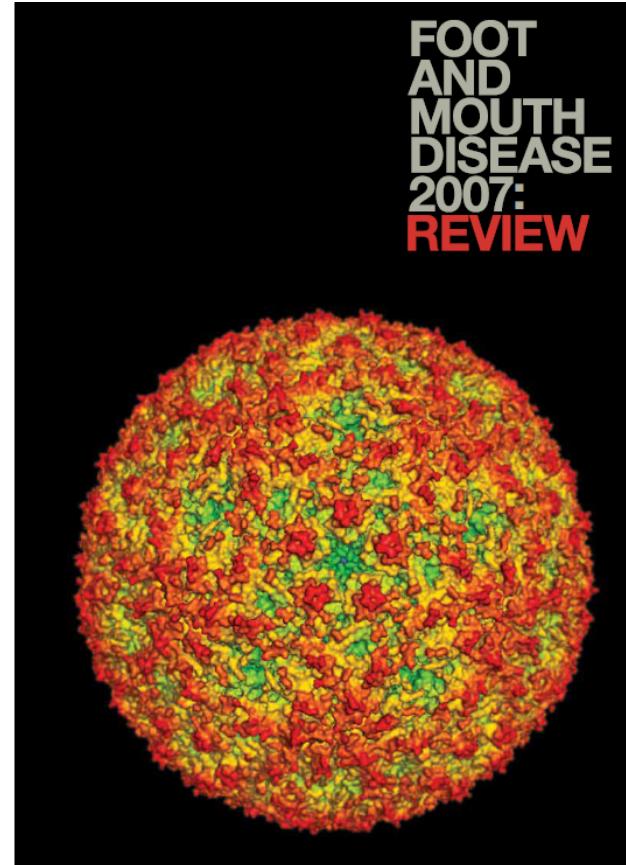
57 premises infected before diagnosis.

6 million animals killed

£8bn cost estimate

Postponed UK General election

1967 contingency plans outdated, new farming methods significantly changed profile of infection.



Case Study – Foot & Mouth

F7 Fail to notice situation has changed

Whilst the contingency planning was there, it was not up to date, and unable to cope with a degrading situation. Because of the incubation period of diseases there is always a lag between what is known and what is happening.

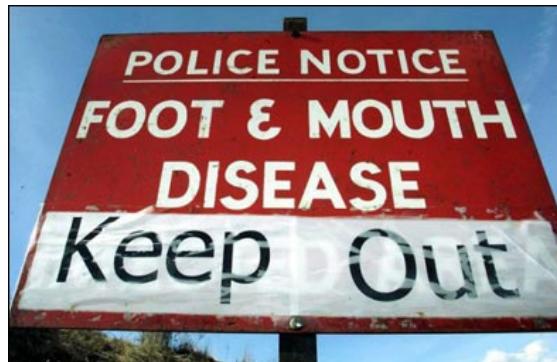
F9 Pick approach we are comfortable with

The plan was based on an approach that was comfortable instead of one that was pertinent to the situation.

F12 Fail to prepare for chaos

An outbreak of a disease is a classic chaotic situation where swift and decisive action is needed, and the key to success is preparation of contingency plans. While there were some failures of execution of the plans the main cause of the problem was that the plans had become flawed, due to failure to recognize impacts of changes in agricultural practice over 3 decades.

Problem Space Characteristics	Approach taken to solve Problem			
	Simple	Complicated	Complex	Chaos
Simple	Success – tasks done quickly, efficiently and consistently. 	Inefficient – over use of process, generation of unwanted documentation and solution potentially over-engineered. 	Inefficient – no economies of scale. 	Inefficient – no delegation, decision maker overwhelmed by detail. 
Complicated	Unsuccessful outcome – system interacts under-stood, emergence managed and large team coordinated. 	Success – complicated interactions under-stood, emergence managed and large team coordinated. 	Inefficient and possibly failure – as parallel approaches waste resources and in subsequent phases engage in expensive rework.  	Highly inefficient and probably failure – inter-dependencies unlikely to be under stood by decision maker. 
Complex	Unsuccessful outcome – stakeholders will diverge, change path will be un-directed. 	Unsuccessful outcome – environment will change faster than the project can deliver. Project will continually restart. 	Success – tempo of delivery matches environmental change, emergent behaviour managed. 	Unsuccessful outcome – decision maker unable to sense changes in the environment quickly enough. 
Chaos	Unsuccessful outcome – mechanism approach unable to cope with unplanned situation. 	Unsuccessful outcome – time taken to understand the problem re-sults in increased in-stability. Stakeholders 'vote with their feet' 	Unsuccessful outcome – parallel approaches insufficiently coherent to stabilise the situation. 	Success – situation stabilised. 

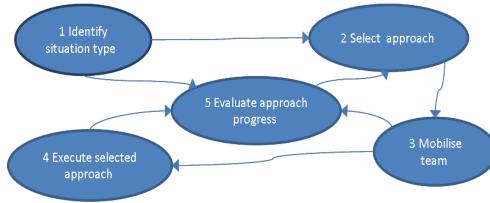


Findings.

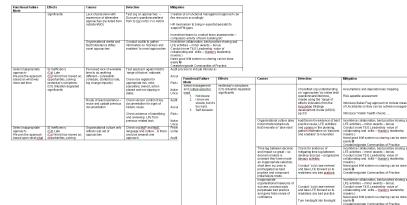
We have proposed a two stage tailoring process...

Identify the space you are in.... then traditional tailoring.

We have developed a simple functional model of this initial tailoring phase...



We have conducted a Functional Failure Mode Analysis on the developed tailoring functional model...



We have used case studies to illustrate appropriate and inappropriate approaches....

		Approaches take to solve Problem		
		Simple	Complex	Others
Problematic Characteristics	Cause	Unsuccessful solution	Success - tasks done sequentially and sequentially	Inefficient - no involvement of stakeholders
		Unsuccessful solution	Success - tasks done sequentially and sequentially	Inefficient - no involvement of stakeholders
Problematic Characteristics	Cause	Unsuccessful solution	Success - tasks done sequentially and sequentially	Inefficient - no involvement of stakeholders
		Unsuccessful solution	Success - tasks done sequentially and sequentially	Inefficient - no involvement of stakeholders

Findings.

Conventional Systems Engineering (SE Handbook) “Understand – Plan – Do” paradigm only works in a ‘sweet spot’ when simple processes are insufficient and before the situation becomes genuinely complex.

Systems approaches (as opposed to SE) are useful in the simple and complex spaces.

Systems approaches can help prevent situations becoming chaotic, and can help prepare for chaotic situations. They are too slow to be useful when chaos hits.

Findings

		Approach taken to solve Problem			
		Simple	Complicated	Complex	Chaos
Problem Space Characteristics	Simple	Success – tasks done quickly, efficiently and consistently. R	Inefficient – over use of process, generation of unwanted documentation and solution potentially over-engineered. R	Inefficient – no economies of scale. R	Inefficient – no delegation, decision maker overwhelmed by detail. FM
	Complicated	Unsuccessful outcome as system inter-dependencies and emergence not managed C	Success – complicated interactions understood, emergence managed and large team coordinated S	Inefficient and possibly failure – as parallel approaches waste resources and subsequent phases engage in expensive framework. W	Highly inefficient and probably failure – inter-dependencies unlikely to be understood by decision maker W
	Complex	Unsuccessful outcome – stakeholders will diverge, change path will be undirected FC	Unsuccessful outcome – environment will change faster than the project can deliver. Project will continually restart V, 15288	Success – tempo of delivery matches environment and behaviour W	Unsuccessful outcome – decision maker unable to sense changes in the environment quickly enough W
	Chaos	Unsuccessful outcome – mechanistic approach unable to cope with unplanned changes FC	Unsuccessful outcome – time taken to understand the problem results in increased instability. Stakeholders 'vote with their feet' V, 15288	Unsuccessful outcome – parallel approaches insufficiently coherent to stabilise the situation. V, 15288	Success – situation stabilised. FC

Help

LEAD
'Sweet Spot'

Help
prepare
for –
don't do.

So What???



25th anniversary
annual INCOSE
international symposium
Seattle, WA
July 13 - 16, 2015

Foresight from Hindsight...

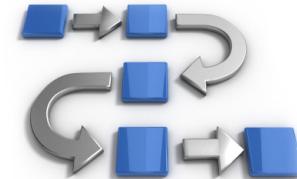


- Clear processes for each space, the new two phase tailoring process as well as a process to detect when the space has shifted.



- A culture that recognises no single approach is 'correct'; that celebrates diversity; and, has stories and myths of right/wrong approaches in the 4 spaces to illustrate 'why we do things this way round here'

- People who understand that the spaces exist, know the right approaches to take in each space and who to involve in what situation



- Organisations with measures and targets for each space and the ability to deploy people with the right skills and experience quickly



Any questions?



Copyright © 2015 Rolls-Royce plc and Crown Copyright. Published and used by INCOSE with permission. This paper represents the views of the authors, and does not represent the position of either Rolls-Royce or the MOD



Rolls-Royce

25th anniversary
annual INCOSE
international symposium
Seattle, WA
July 13 - 16, 2015