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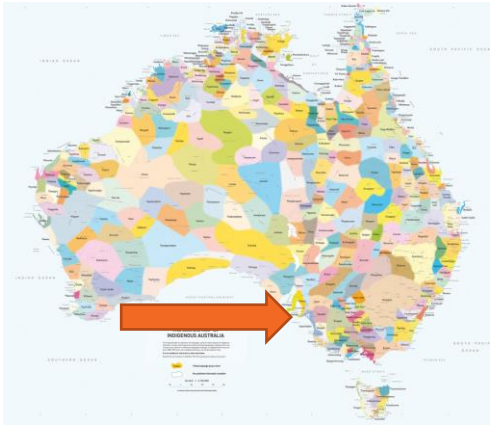
ACKNOWLEDGEMENT OF COUNTRY

In the spirit of reconciliation with our First Nations Peoples, I acknowledge the Traditional Custodians of country throughout Australia and their connections to land, sea and community.

We pay our respect to their elders past and present and extend that respect to all Aboriginal and Torres Strait Islander peoples today.

Today I am presenting from the land of the Kaurna people.



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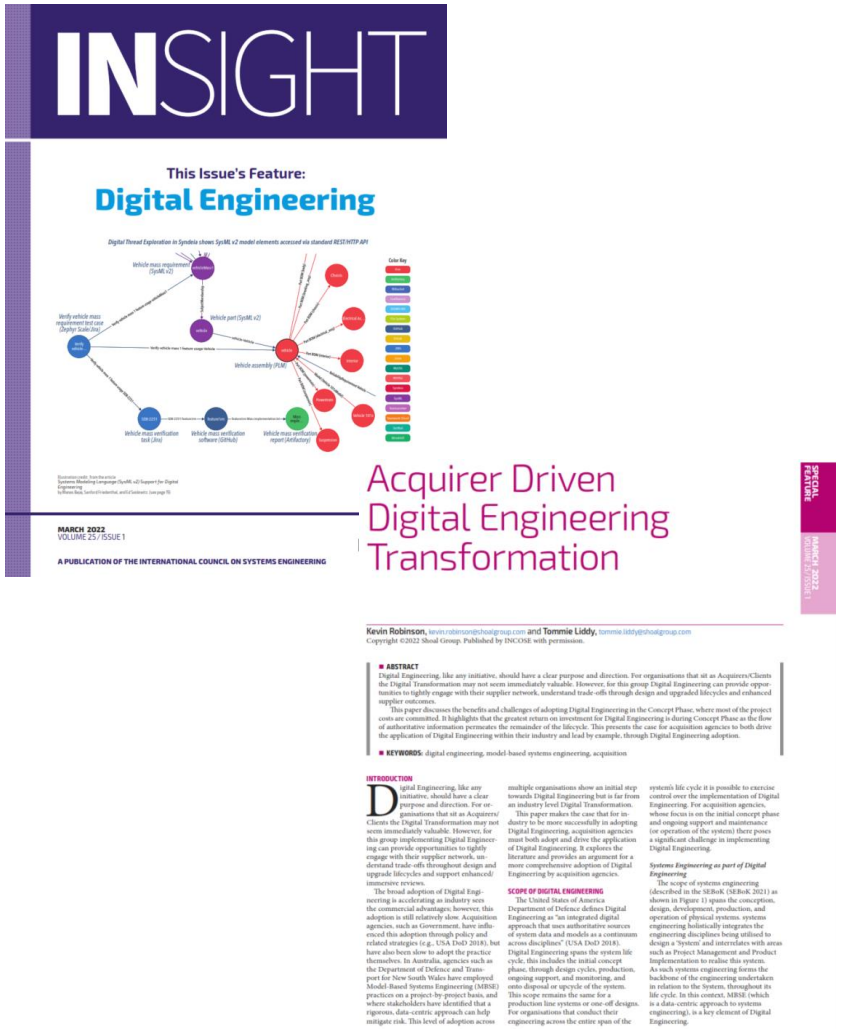
Kevin Robinson & Tommie Liddy

DIGITAL ENGINEERING:

An opportunity for acquisition agencies

OUTLINE

- Introduction. Motivation. Purpose.
- Digital Engineering
- Benefits of Digital Engineering
- Acquire-led DE transformation
- Benefits to supplier
- Challenges for the acquirer
- Summary


INSIGHT

This Issue's Feature:

Digital Engineering

MARCH 2022
VOLUME 25 / ISSUE 1

A PUBLICATION OF THE INTERNATIONAL COUNCIL ON SYSTEMS ENGINEERING

SPECIAL FEATURE

Acquirer Driven Digital Engineering Transformation

Kevin Robinson, kevin.robinson@shoalgroup.com and Tommie Liddy, tommie.liddy@shoalgroup.com

ABSTRACT

Digital Engineering, like any initiative, should have a clear purpose and direction. For organisations that sit as Acquirers/Clients the Digital Transformation may not seem immediately valuable. However, for this group Digital Engineering can provide opportunities to tightly engage with their supplier network, understand trade-offs through design and upgraded lifecycles and enhanced supplier outcomes.

This paper discusses the benefits and challenges of adopting Digital Engineering in the Concept Phase, where most of the project costs are committed. It highlights that the greatest return on investment for Digital Engineering is during Concept Phase as the flow of authoritative information permeates the remainder of the lifecycle. This presents the case for acquisition agencies to both drive the application of Digital Engineering within their industry and lead by example, through Digital Engineering adoption.

KEYWORDS: digital engineering, model-based systems engineering, acquisition

INTRODUCTION

Digital Engineering, like any initiative, should have a clear purpose and direction. For organisations that sit as Acquirers/Clients the Digital Transformation may not seem immediately valuable. However, for this group implementing Digital Engineering can provide opportunities to tightly engage with their supplier network, understand trade-offs throughout design and upgrade lifecycles and support enhanced/immersive reviews.

The broad adoption of Digital Engineering is accelerating as industry sees the commercial advantages, however, this adoption is still relatively slow. Acquisition agencies, such as Government, have influenced this adoption through policy and related strategies (e.g., USA DoD 2018), but have also been slow to adopt the practice themselves. In Australia, agencies such as the Department of Defence and Transport for New South Wales have employed Model-Based Systems Engineering (MBSE) practices on a project-by-project basis, and where stakeholders have identified that a rigorous, data-centric approach can help mitigate risk. This level of adoption across multiple organisations show an initial step towards Digital Engineering but is far from an industry level Digital Transformation.

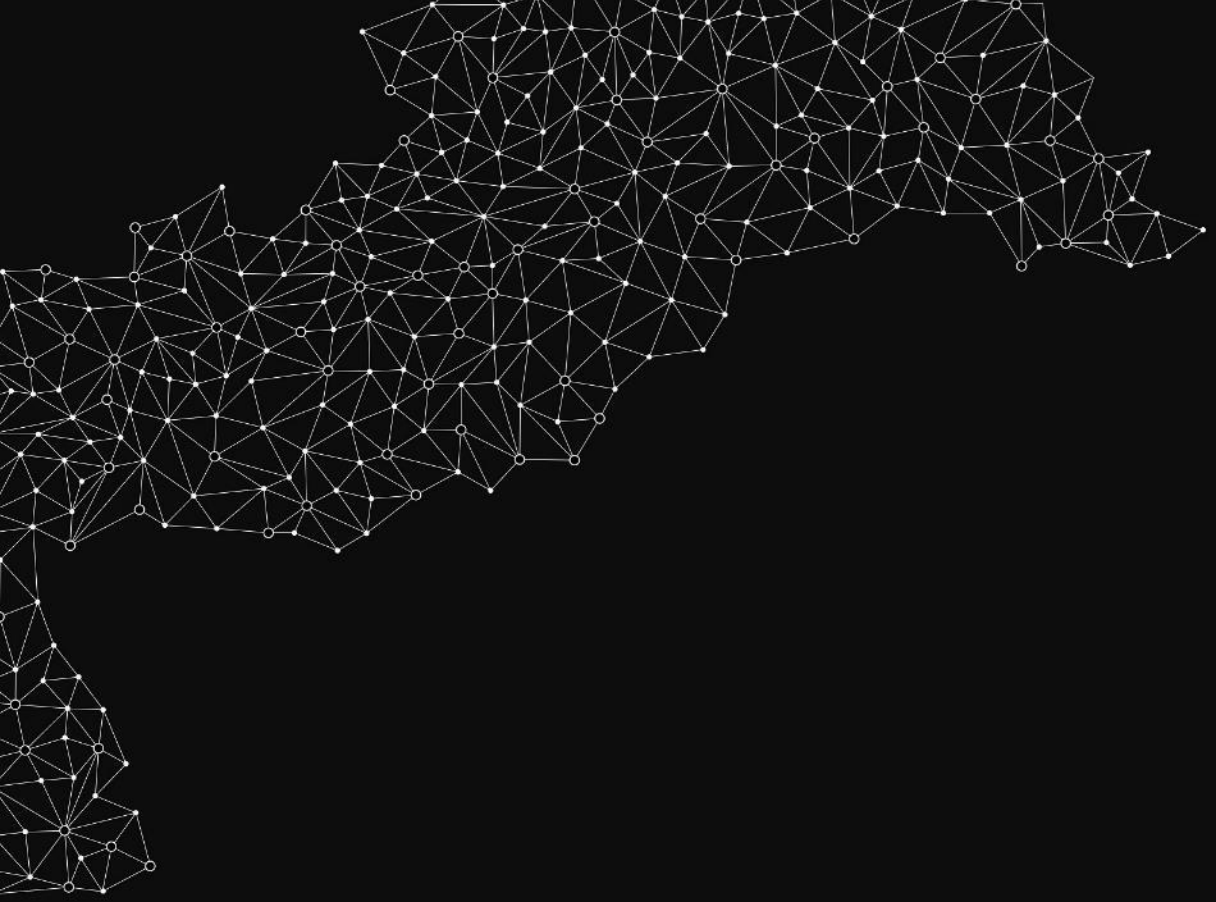
This paper makes the case that for industry to be more successfully in adopting Digital Engineering, acquisition agencies must both adopt and drive the application of Digital Engineering. It explores the literature and provides an argument for a more comprehensive adoption of Digital Engineering by acquisition agencies.

SCOPE OF DIGITAL ENGINEERING

The United States of America Department of Defence defines Digital Engineering as "an integrated digital approach that uses authoritative sources of system data and models as a continuum across disciplines" (USA DoD 2018). Digital Engineering spans the system life cycle, this includes the initial concept phase, through design cycles, production, ongoing support, and monitoring, and onto disposal or upcycle of the system. This scope remains the same for a production line systems or one-off designs. For organisations that conduct their engineering across the entire span of the system's life cycle it is possible to exercise control over the implementation of Digital Engineering. For acquisition agencies, whose focus is on the initial concept phase and ongoing support and maintenance (or operation of the system) there poses a significant challenge in implementing Digital Engineering.

Systems Engineering as part of Digital Engineering

The scope of systems engineering (described in the SEBoK (SEBoK 2021) as shown in Figure 1) spans the conception, design, development, production, and operation of physical systems. systems engineering holistically integrates the engineering disciplines being utilised to design a 'System' and interrelates with areas such as Project Management and Product Implementation to realise this system. As such systems engineering forms the backbone of the engineering undertaken in relation to the System, throughout its life cycle. In this context, MBSE (which is a data-centric approach to systems engineering), is a key element of Digital Engineering.



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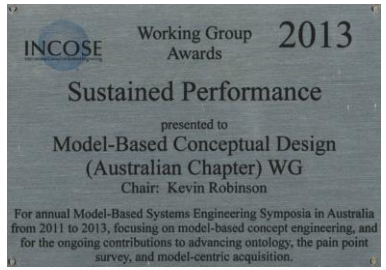
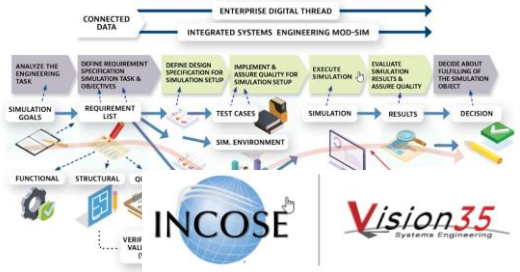
INTRODUCTION

A BIT ABOUT ME

Kevin Robinson
Shoal's Chief Engineer
Head of Engineering and Innovation

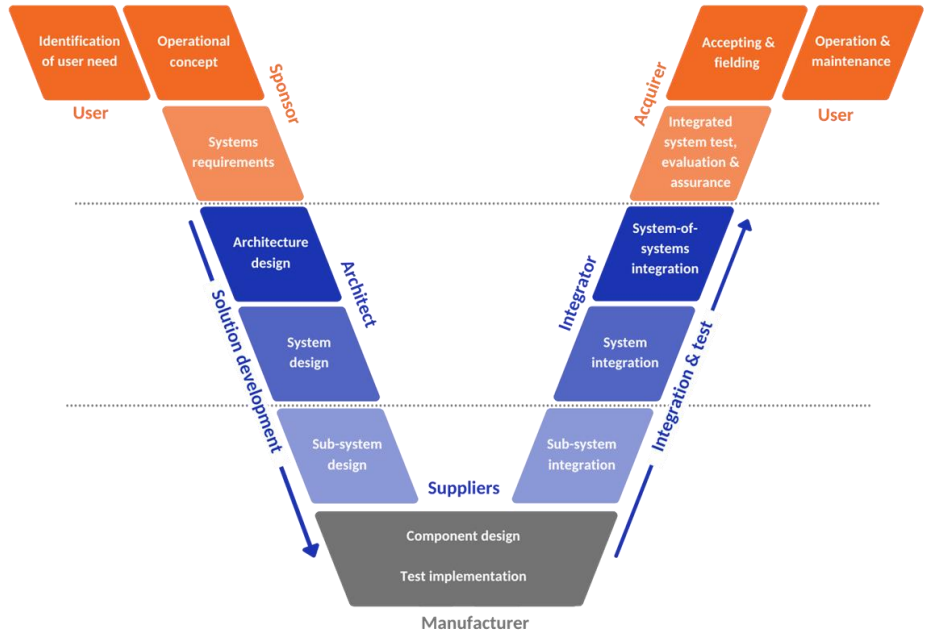




IS2016 - Thursday Keynote - Kevin Robinson - 26th INCOSE International Conference
799 views • 5 years ago
INCOSE YouTube
Group Leader, DSTO Speaking Topic: Improving conceptual design - Opportunities for model-based methodologies.

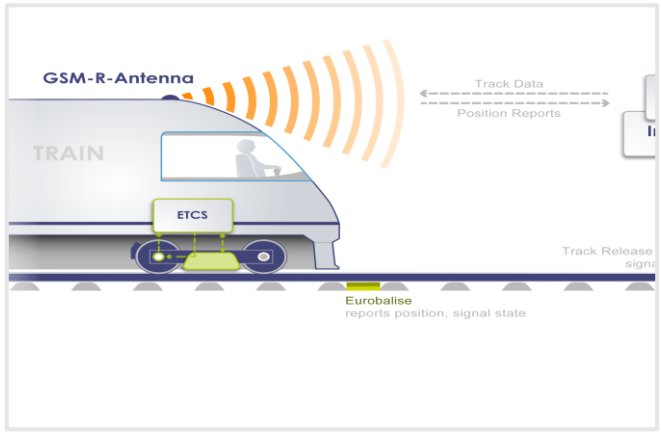
A BIT ABOUT SHOAL GROUP

- Complex systems design house
  - Digital Engineering the front half of the SE Vee
- Supporting government, industry and research agencies
- Almost 70 Systems Engineers
  - Digital engineering
  - Conceptual design
  - Systems architecture
  - Modelling, simulation and analysis



SHOAL'S SUCCESSES

Navy Hunter Class Frigates



TfNSW Digital Systems

KiwiRail Interislander Ferry (iREX)

CHORUS Project

Land Combat Vehicle System

Sydney Metro Systems Architecture

DIGITAL ENGINEERING IN SHOAL

- An approach to Systems Engineering
  - Significant investment in the research and contribution to the BoK

- *Business-as-usual* since 2005
  - First “real-world” acquisition project
    - Ground-based Air Defence Acquisition
    - In partnership with Defence

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MOTIVATION AND PURPOSE

RESEARCH MOTIVATION

- Professional motivation
  - Desire to see the benefits of DE realised earlier in the lifecycle
    - Model-based Conceptual Design (MBCD)


Credit: abc.net.au

- Personal motivation
  - Bushfires are on my door step
    - Use case for realising the benefits of MBCD
  - Good collaboration with David Flanigan


Credit: abc.net.au

PRESENTATION PURPOSE

- Present the case for acquisition agencies to:
  - Adopt Digital Engineering
  - Drive the adoption of Digital Engineering

- Acquisition agencies are responsible for
  - Ensuring the systems engineering is delivering outcomes
  - Initiating the life cycle to engineer a system

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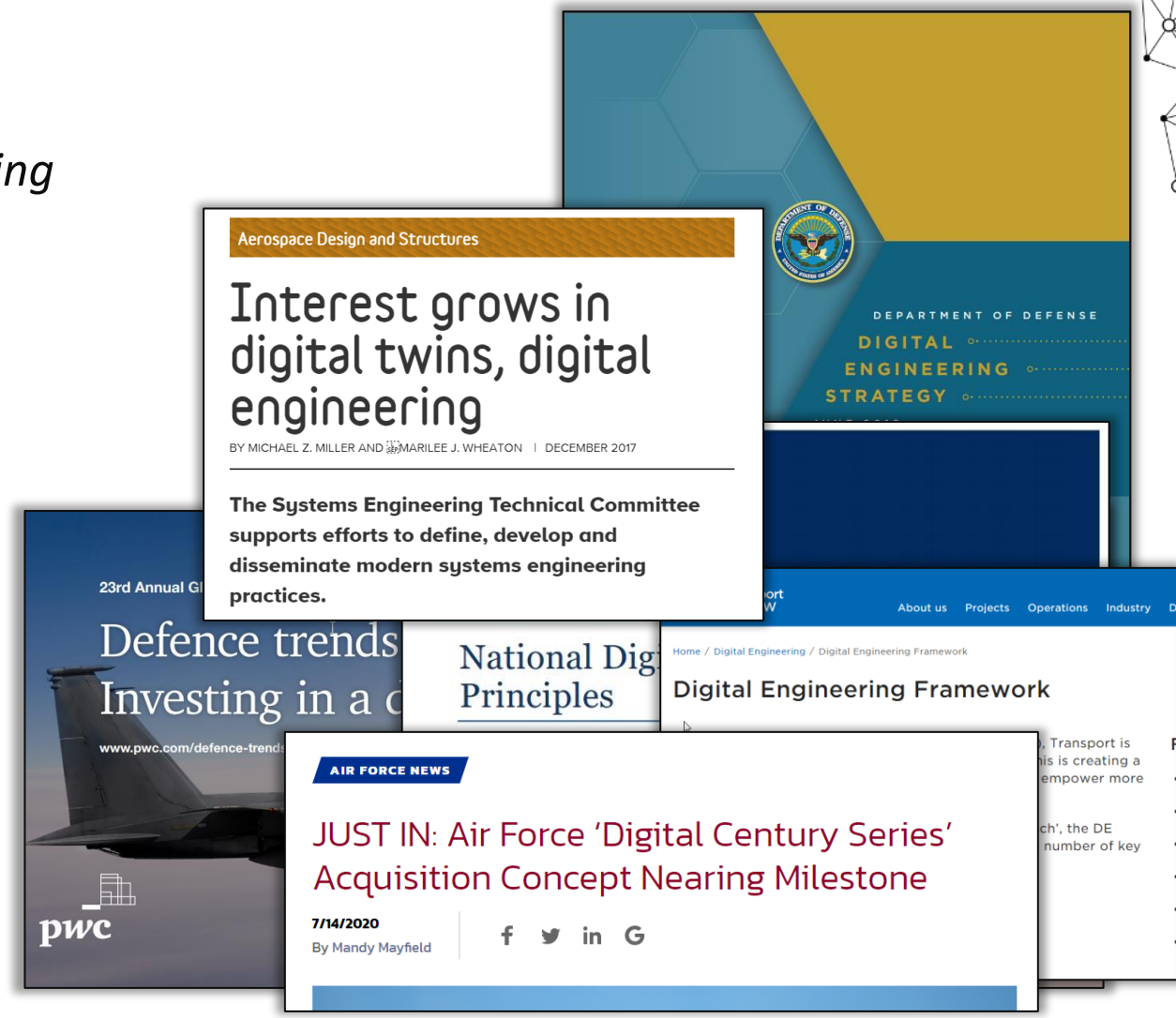
DIGITAL ENGINEERING

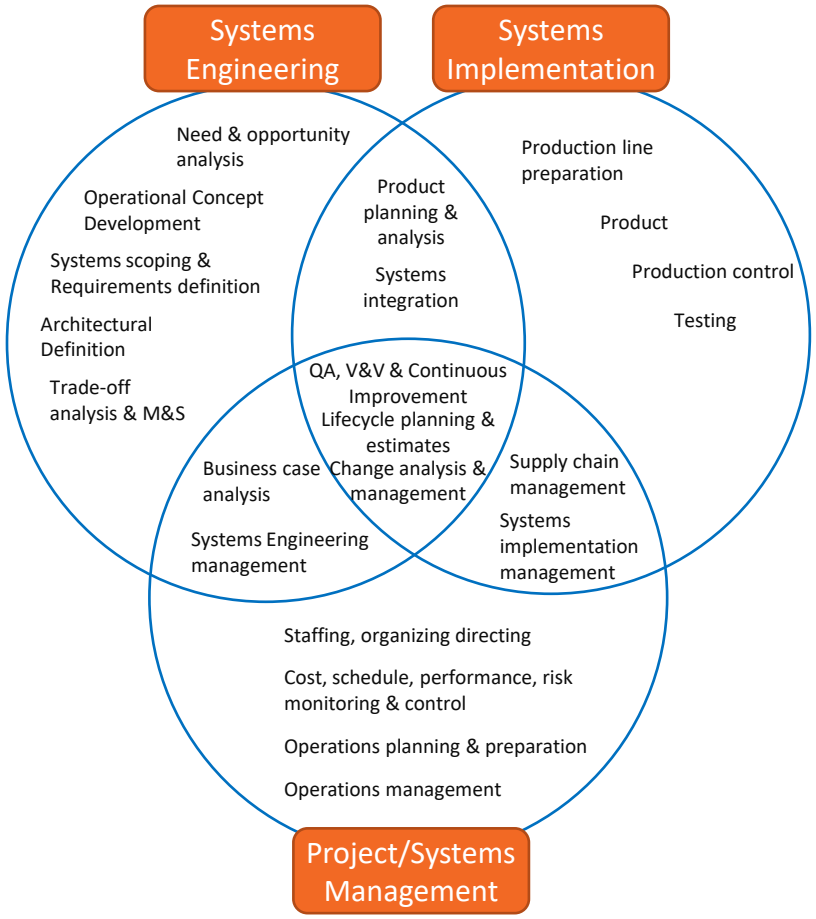
CONTEXT

- The world is moving to digital engineering
  - DoD Digital Engineering Strategy (2018)

    "…the Department is transforming its engineering practices to digital engineering, incorporating technological innovations into an integrated, digital, model-based approach."
- Digital engineering is being pushed further down into the supply chain as a requirement
- Digital engineering enables stakeholders to solve problems in ground-breaking ways, addressing long-standing challenges with linear design and stove-piped information & communications



SCOPE OF DE



Redrawn from SEBOK

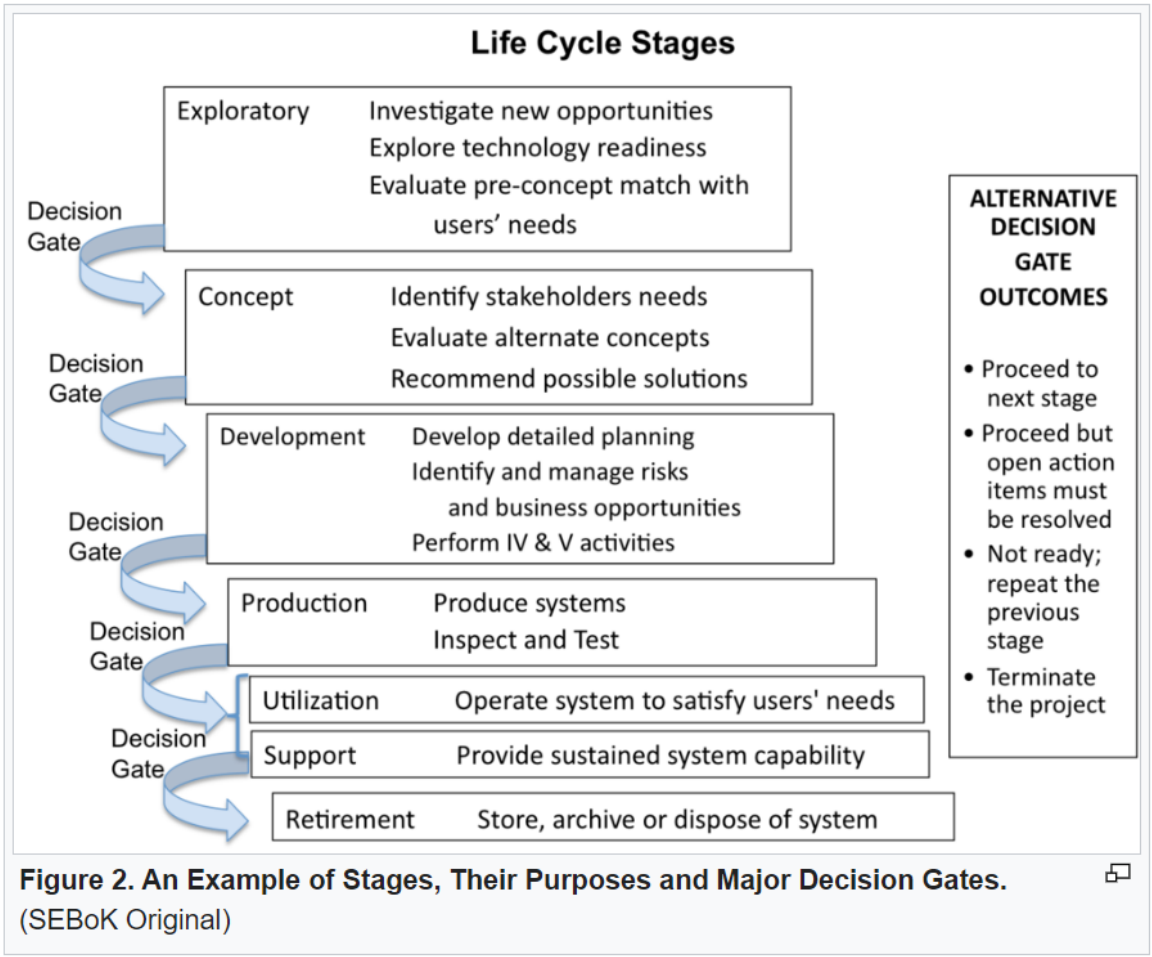


Figure 2. An Example of Stages, Their Purposes and Major Decision Gates.
(SEBoK Original)

https://www.sebokwiki.org/wiki/SEBoK_Introduction

DIGITAL ENGINEERING: THREADS AND TWINS

Strategy

Requirements

Context

Regulations

Designs (CAD)

Software

Performance data

Bill Of Materials (BOM)

Supply Chain data

Constraints

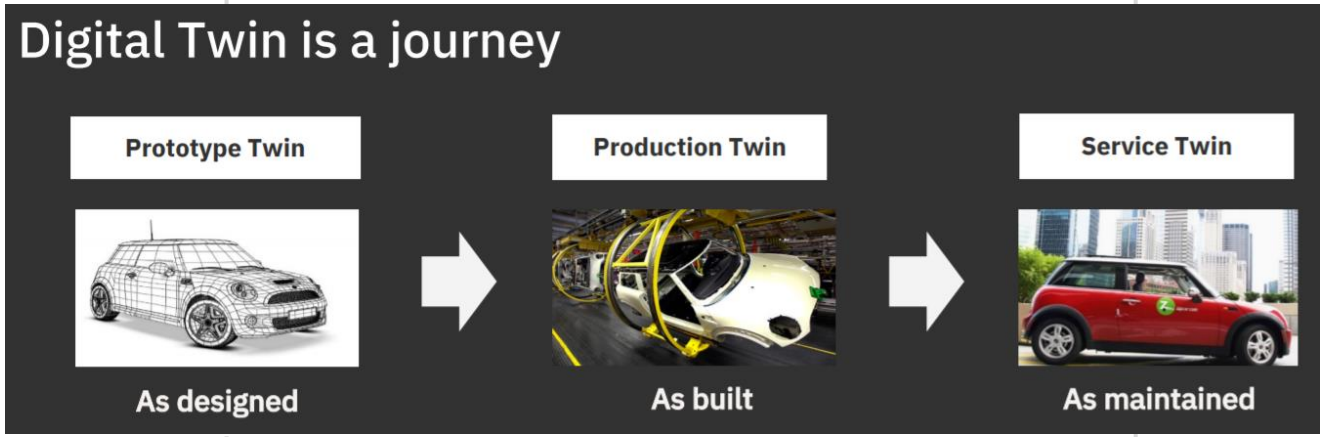
Measures of Effectiveness

Measures of Performance

Manufacturing plans / processes

Materials / Lots / Serial numbers

Nonconformance data



Resource planning

Logistics / supply chain Management info

Inspections / tests / V&V

Operating hours

Operating conditions

Inspections / sensor reporting

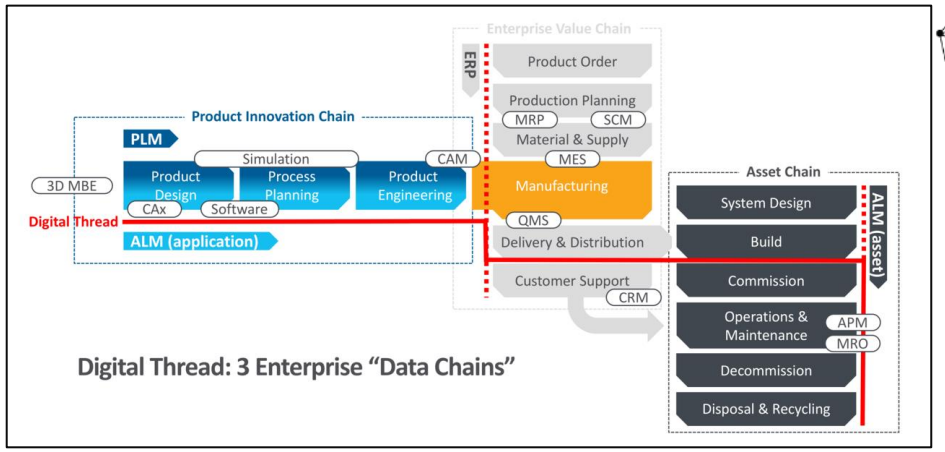
Performance observations

Consumable monitoring (e.g. fuel)

Predicted performance analysis

DIGITAL TWINS AND DIGITAL THREADS

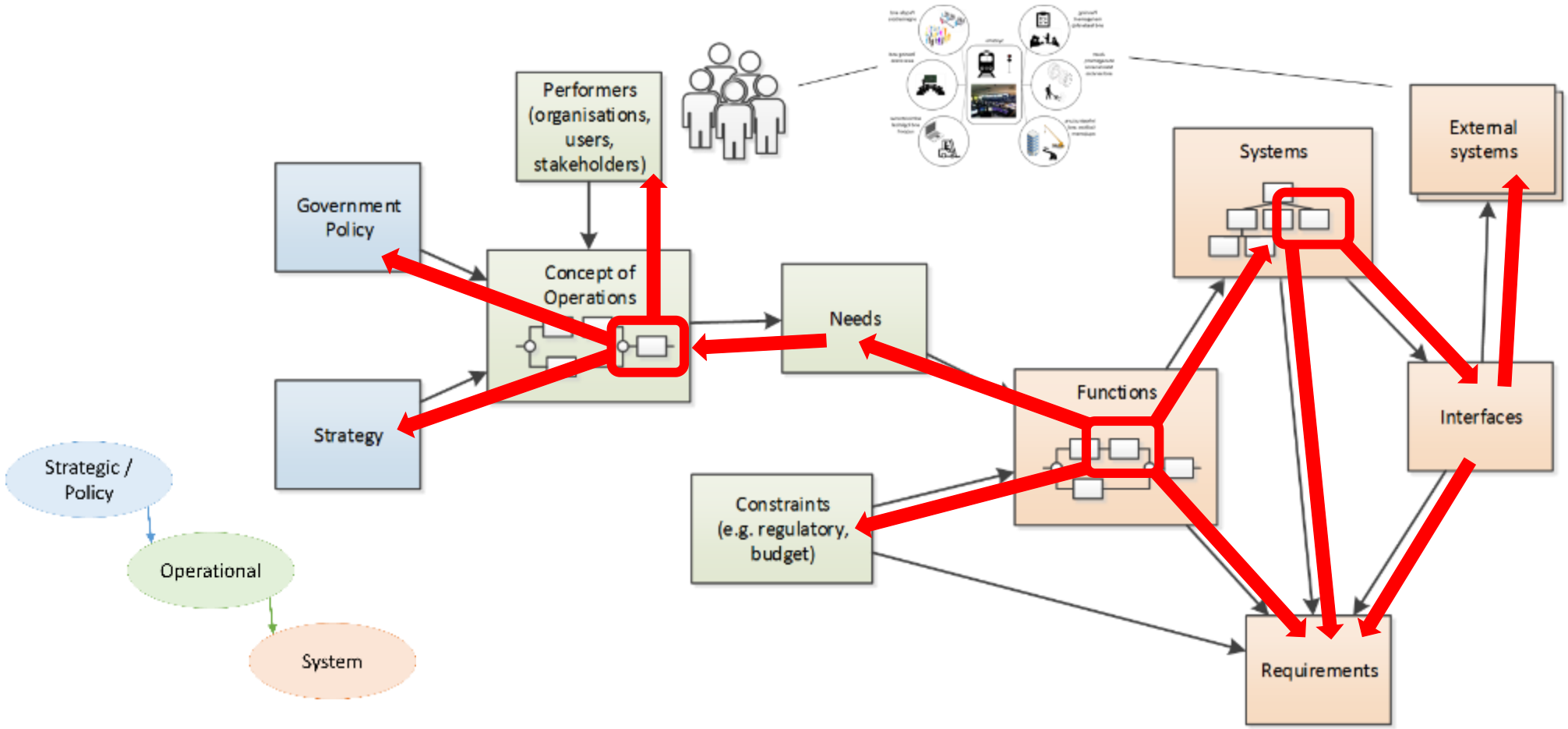
- **Digital Thread**: "A single, seamless strand of data that stretches from the initial design concept to the part end-of-life" (From 3D Opportunity and the Digital Thread)
  - **Unifies diverse but interrelated data sets**: linking all capabilities such as the designs, performance data, product data, supply chain data, and software that goes into creating the product
  - Data set is enabled with **'real-time' data synchronization** so upstream and downstream information is available to all users
  - In an **enterprise setting**, most commonly connect data sets from CAD, product lifecycle management (PLM), Industrial IoT (IIoT), ERP, CRM, MES, BOM, and more
  - This data unification is a necessary pre-requisite to building a true digital twin
- **Digital Twin**: digital model that virtually represents its physical counterpart
  - **Not restricted to products or physical "things"**, they can also be developed for operational processes, or even a worker's task
  - For physical systems, a digital twin is used to better understand the physical counterpart and offer insights, or even predict how the physical counterpart will react or behave - Often includes business system data and sensor data, so **digital twins truly reflect the physical counterpart and its environment**



Sources: *What does a digital thread mean and how it differs from digital twin*, Challenge Advisory; *Digital Twin vs. Digital Thread: Defining the Concepts*, PTC

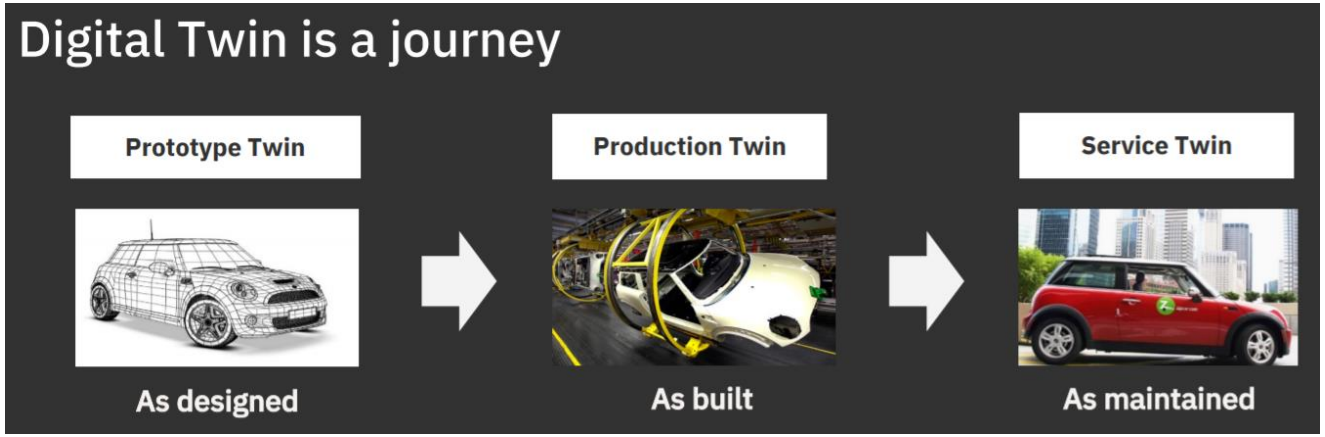
DIGITAL THREAD

- Government strategy to system requirements



DIGITAL TWINS

- Evolution of a Digital Twin
  - Prototype Twin (as designed)
    - Instantiation: Model-Based Systems Engineering
    - No physical object, no real-time data
  - Production Twin (as built)
    - Instantiation: Simulation model with real-time data
    - Has a correlating physical object and real time data
  - Service Twin (as used / maintained)
    - Instantiation: Prediction data (optimisation, attributes, performance characteristics, environmental response, failure modes); augmented reality
    - Has a correlating physical object and real time data. Aka ‘digital shadow’
    - Data from the real artifact captured and compared to information in the virtual prototype

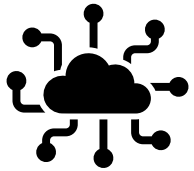


Source: *The role of Simulation and AI in the implementation of a Digital Twin*, Dr. Graham Bleakley. IBM Offering manager Modelling and MBSE solutions;

DE CONCEPTS

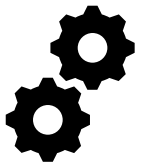
The ‘model’ is essential, it is the “current collective understanding”

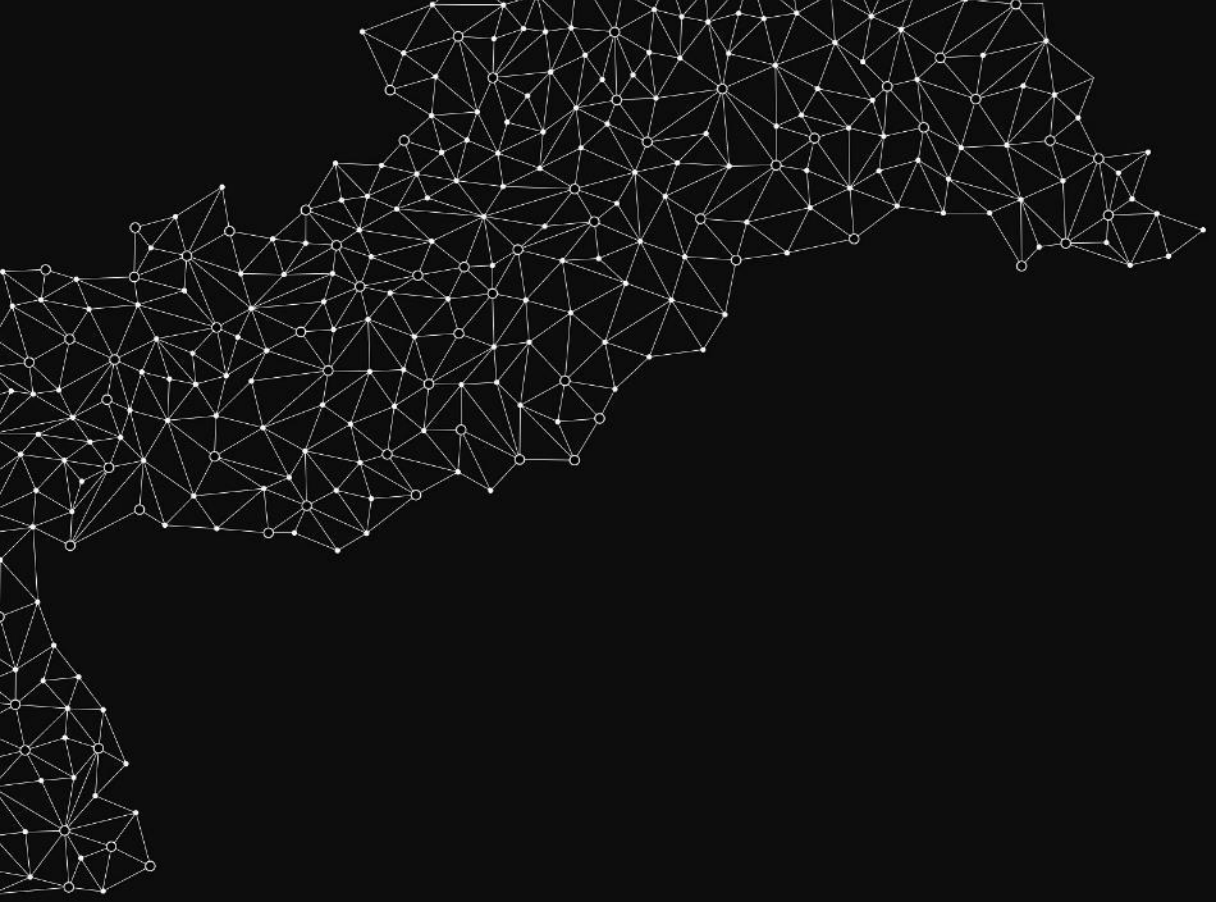
The ‘model’ information elements are connected and traceable



The ‘model’ is provided to teams throughout the life cycle

Documents and other artefacts are generated consistently





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BENEFITS OF DE

THE BENEFIT

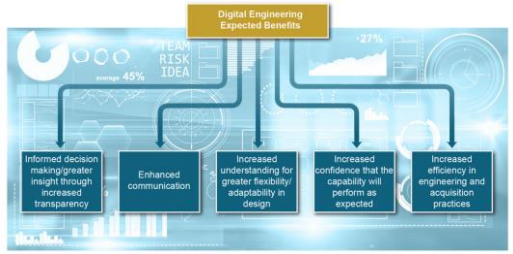
“Digital Engineering solves the problems that you never knew you had”

Tim Cater, Shoal Engineering Lead

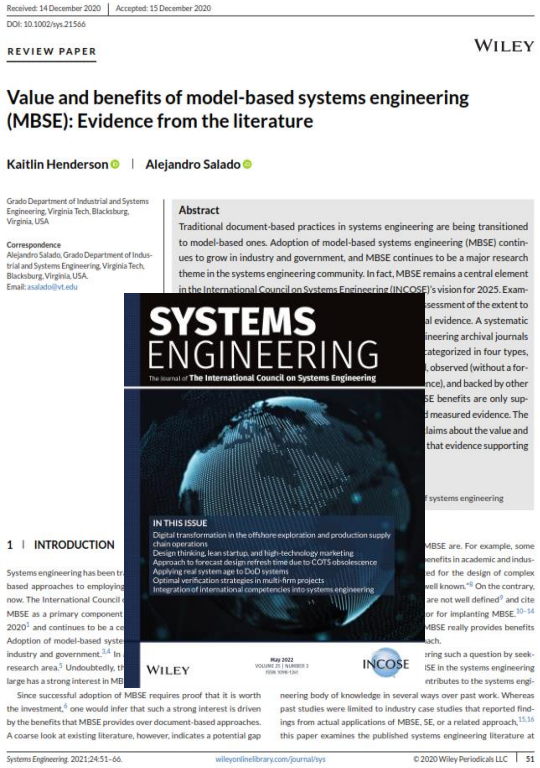
PERCEIVED BENEFITS*

- Enhanced communication
- Increased traceability
- Reduced errors
- Improve consistency
- Better accessibility

- Kevin's view
  - Better ability to elicit, structure, capture, communicate and analyse information on the system being engineered



DoD Digital Engineering Strategy (2018)



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REVIEW PAPER

WILEY

Value and benefits of model-based systems engineering (MBSE): Evidence from the literature

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Abstract

Traditional document-based practices in systems engineering are being transitioned to model-based ones. Adoption of model-based systems engineering (MBSE) continues to grow in industry and government, and MBSE continues to be a major research theme in the systems engineering community. In fact, MBSE remains a central element in the International Council on Systems Engineering (INCOSE)'s vision for 2025. Exam-

SYSTEMS ENGINEERING

The Journal of The International Council on Systems Engineering

IN THIS ISSUE

Digital transformation in the offshore exploration and production supply chain operations
Design thinking, lean startup, and high-technology marketing
Approach to forecast design refresh time due to COTS obsolescence
Applying real system age to DoD systems
Optimal verification strategies in multi-firm projects
Integration of international competencies into systems engineering

WILEY

INCOSE

1 | INTRODUCTION

Systems engineering has been tr... based approaches to employing... now. The International Council ... MBSE as a primary component ... 2020[1] and continues to be a c... Adoption of model-based syste... industry and government.[3,4] In ... research area.[5] Undoubtedly, t... large has a strong interest in ME...

Since successful adoption of MBSE requires proof that it is worth the investment,[3] one would infer that such a strong interest is driven by the benefits that MBSE provides over document-based approaches. A coarse look at existing literature, however, indicates a potential gap

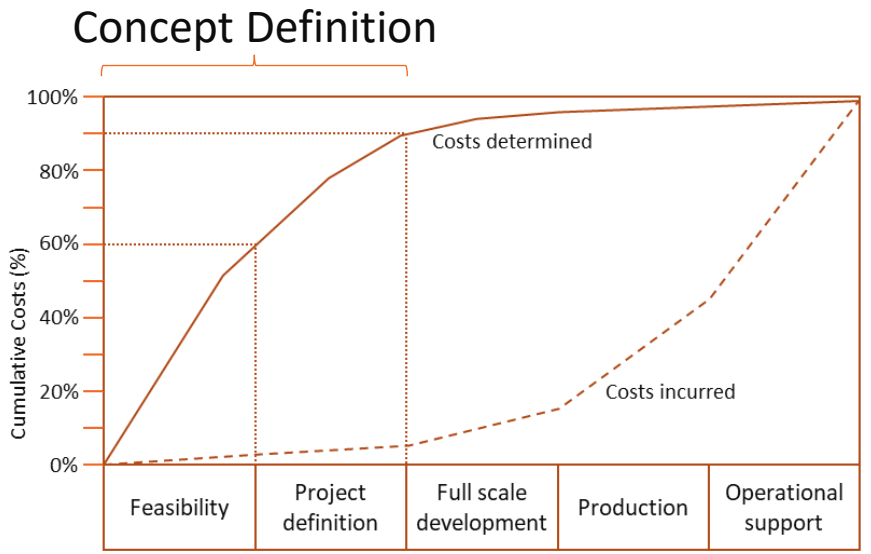
...neering body of knowledge in several ways over past work. Whereas past studies were limited to industry case studies that reported findings from actual applications of MBSE, SE, or a related approach,[15,16] this paper examines the published systems engineering literature at

Systems Engineering. 2021;24:51–66. wileyonlinelibrary.com/journal/sys © 2020 Wiley Periodicals LLC | 51

*Henderson K., and A. Salado. 2020. "Value and Benefits of Model-Based Systems Engineering (MBSE): Evidence from the Literature." Systems Engineering 24 (1): 51–66.

ACQUIRER-LED DE CHANGE

- 1992 - UK's National Audit Office*
  - *"…90% of life cycle costs may be determined by the decisions made before production of a new weapon system begins…"*
- Concept Definition Phase is the obvious place for change
- Concept Definition Phase is an acquirer responsibility



*NAO (National Audit Office (UK)). 1992. "Ministry of Defence: Planning for Lifecycle Costs." White Paper, House of Commons.

SO WHAT FOR THE ACQUIRER?

- Successful projects: higher proportion of their budget spent on mission definition and requirements engineering*
  - A better Concept Definition
- Immediate benefits to the acquirer
  - …with downstream benefits to the supplier:
    - Enhance communication of the problem space
    - Increased traceability to strategic need
    - Reduced errors in the system requirements
    - Improved consistency from concept definition to test and evaluation
    - Better accessibility to stakeholder information and rationale
- Greatest return: early stages of the project

Honour,2013. Systems engineering return on investment, PhD thesis, University of South Australia.

SE activity	Investment
Optimal total SE investment	**14.4%**
Mission / Purpose Definition (MD)	1.3%
Requirements Engineering (RE)	2.0%
System Architecting (SA)	3.9%
System Integration (SI)	2.8%
Verification and Validation (VV)	2.4%
Technical Analysis (TA)	1.8%
Scope Management (SM)	1.4%
Technical Management / Leadership (TM)	3.9%

*(Cook S., and S. Wilson. 2018. "The Case for Investment in Systems Engineering in the Initial Stages of Projects and Programs. Paper presented at the Systems Engineering Test and Evaluation Conference, Sydney, AU, 30 April – 2 May)

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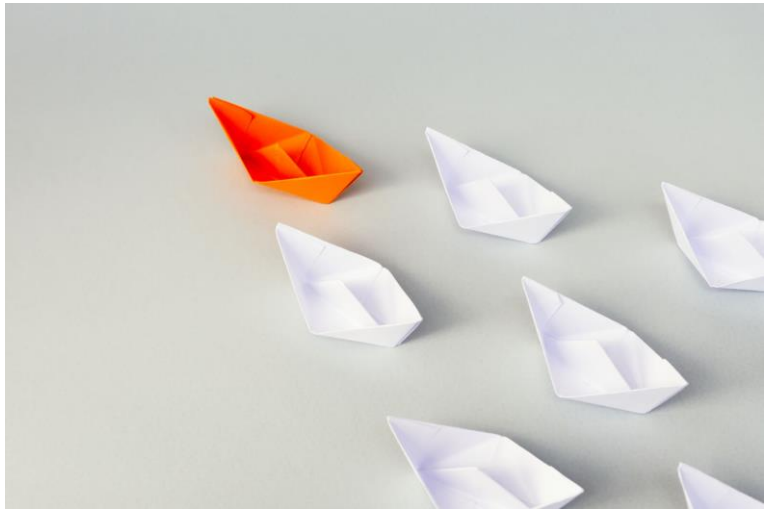
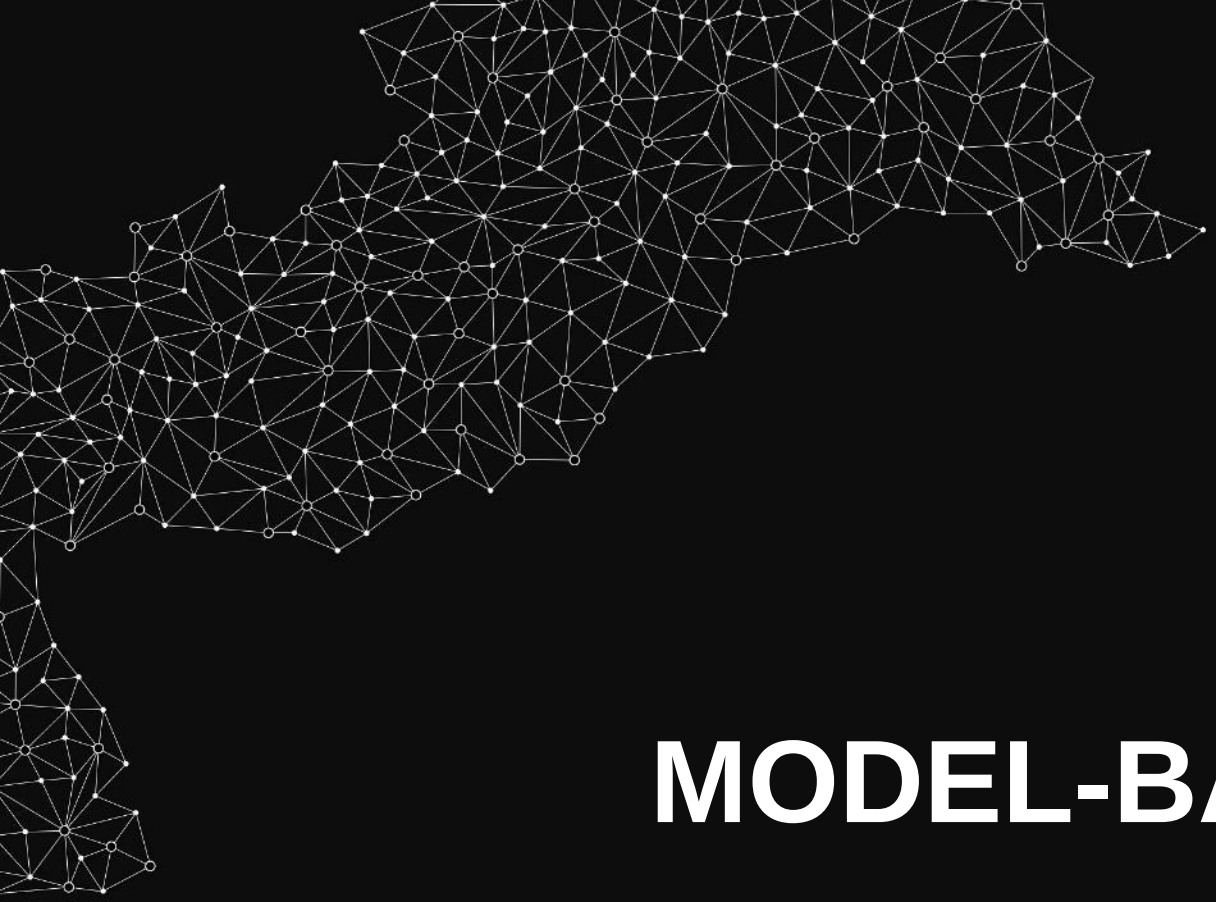
ACQUIRE-LED DIGITAL ENGINEERING TRANSFORMATION

TWO ROLES OF THE ACQUIRER

- Deliver the data-centric artefacts needed for Digital Engineering
  - Across the full life cycle of a system
  - Model-based Conceptual Design

- Leadership, governance and control
  - The use and acceptance of system data-centric artefacts
  - Standardise and define the data-centric approaches and structures to apply





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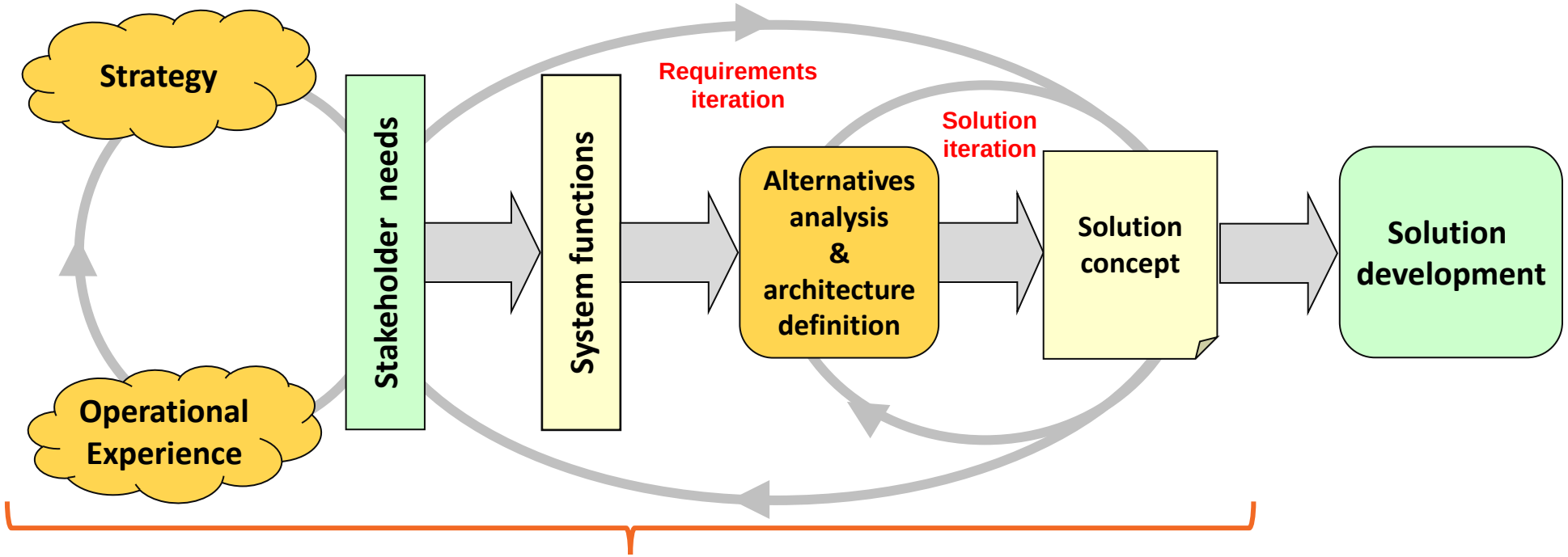
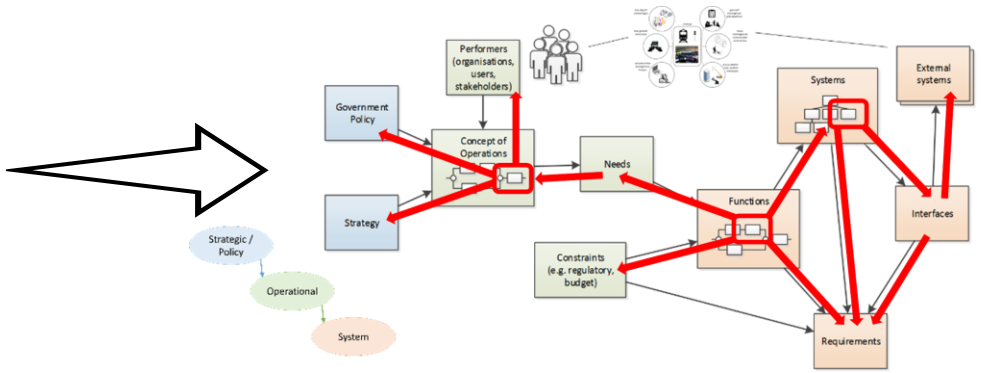
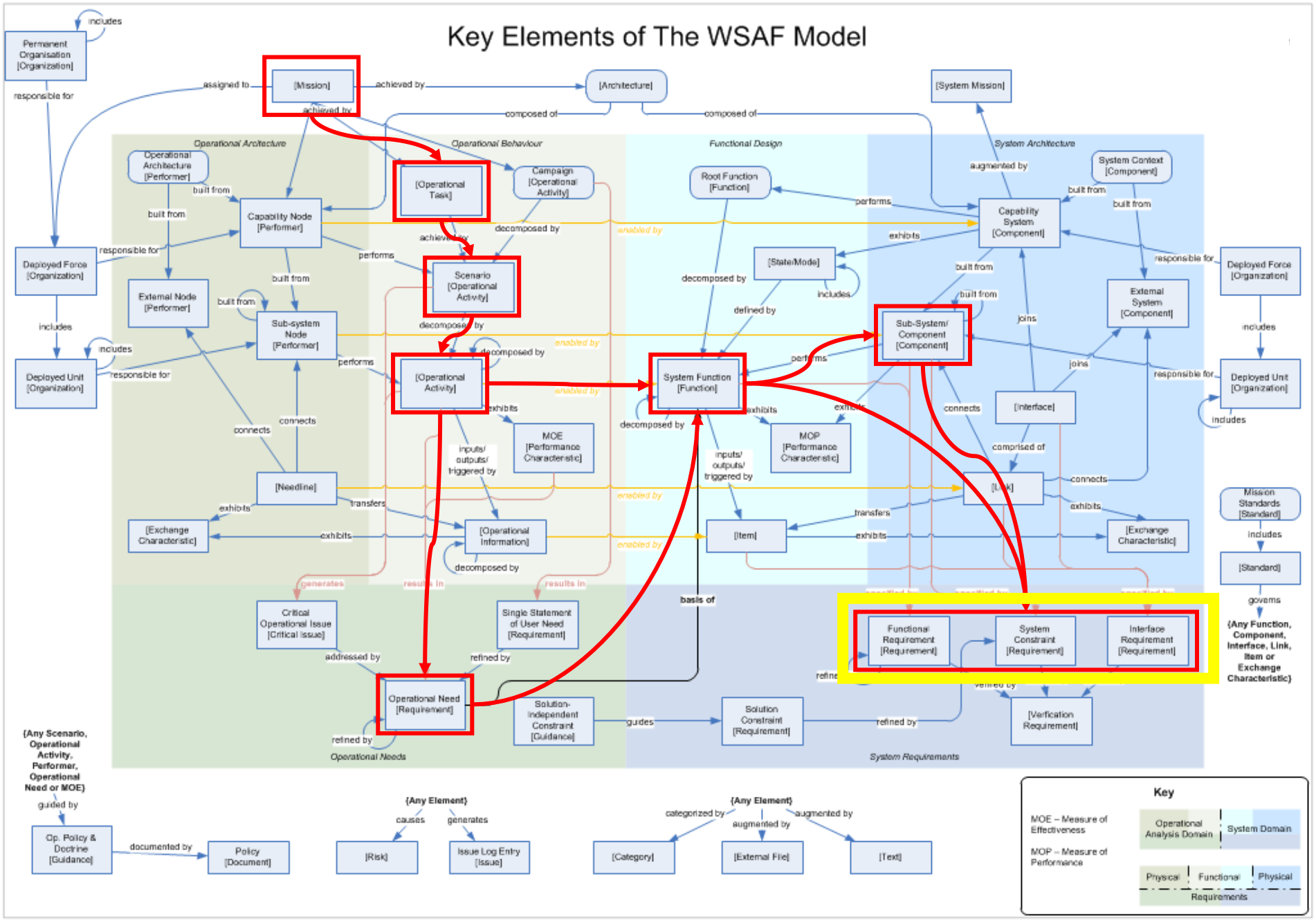
MODEL-BASED CONCEPTUAL DESIGN

CONCEPTUAL DESIGN CYCLE

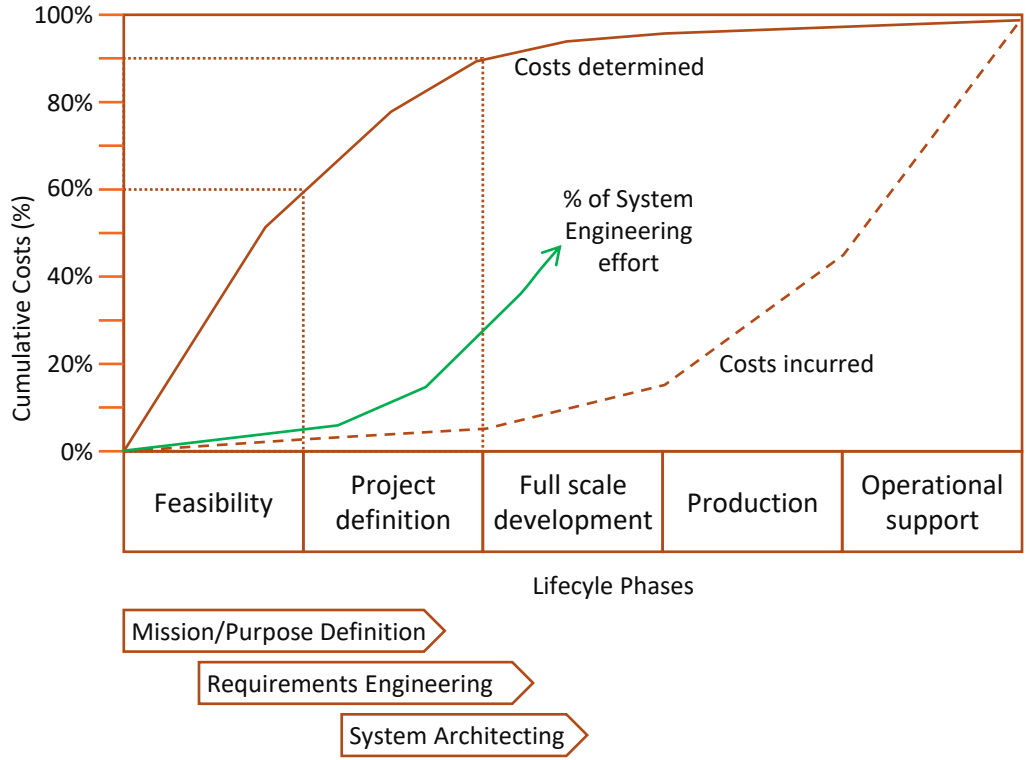





Key Elements of The WSAF Model
Operational Architecture
Operational Behaviour
Functional Design
System Architecture
Operational Needs
System Requirements
[Mission]
[Architecture]
[System Mission]
[Operational Task]
[Operational Activity]
[Operational Information]
Scenario [Operational Activity]
Campaign [Operational Activity]
Capability Node [Performer]
Sub-system Node [Performer]
Operational Architecture [Performer]
External Node [Performer]
Permanent Organisation [Organization]
Deployed Force [Organization]
Deployed Unit [Organization]
[Needline]
[Exchange Characteristic]
MOE [Performance Characteristic]
Critical Operational Issue [Critical Issue]
Single Statement of User Need [Requirement]
Operational Need [Requirement]
Solution-independent Constraint [Guidance]
Root Function [Function]
System Function [Function]
[State/Mode]
MOP [Performance Characteristic]
[Item]
Capability System [Component]
Sub-System/ Component [Component]
System Context [Component]
External System [Component]
[Interface]
[Link]
Functional Requirement [Requirement]
System Constraint [Requirement]
Interface Requirement [Requirement]
Solution Constraint [Requirement]
[Verification Requirement]
Mission Standards [Standard]
[Standard]
{Any Function, Component, Interface, Link, Item or Exchange Characteristic}
{Any Scenario, Operational Activity, Performer, Operational Need or MOE}
Op. Policy & Doctrine [Guidance]
Policy [Document]
{Any Element}
[Risk]
Issue Log Entry [Issue]
[Category]
[External File]
[Text]
Key
MOE – Measure of Effectiveness
MOP – Measure of Performance
Operational Analysis Domain
System Domain
Physical
Functional
Physical
Requirements

RETURN ON INVESTMENT

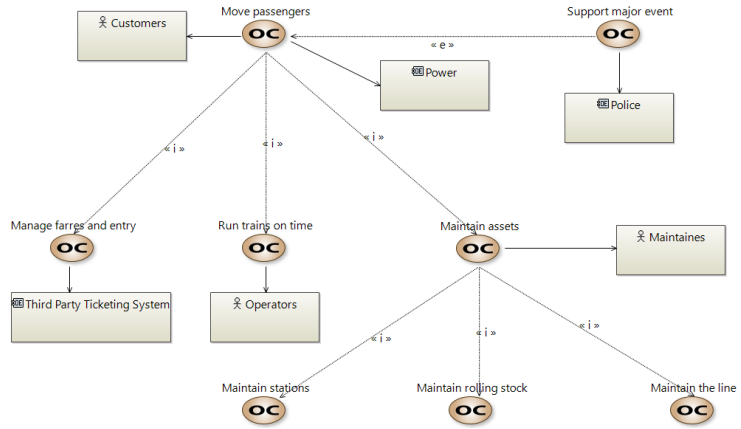
- Eric Honour:
  - 15% spend of project budget on systems engineering provides the best result on project outcomes
  - 40% of that spend:
    - Mission Definition, Requirements Engineering and Systems Architecting
    - 6% of total project budget!
- Must spend that 6% wisely

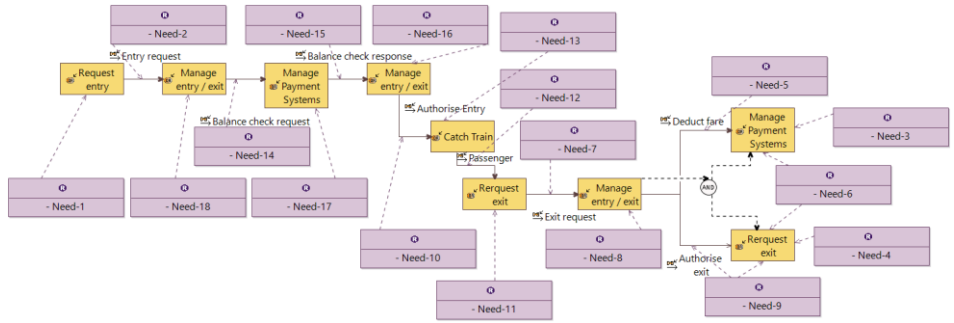


*Honour, E. 2011. "Sizing Systems Engineering Activities to Optimize Return on Investment." Paper presented at the 21st Annual International Symposium of INCOSE, Denver, US-CO, 20-23 June

CONCEPTUAL DESIGN

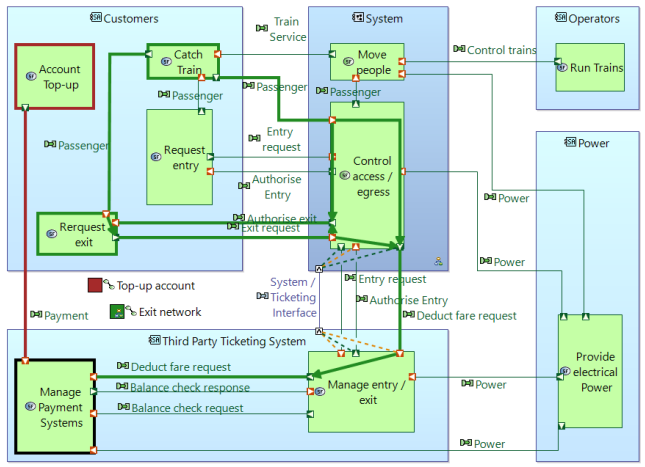
- Structured way to connect business goals / missions to an operational view
- Structured identification of needs / requirements ensures coverage of operations & business goals
- Benefits
  - Provides the basis for further MBSE efforts
  - Trace to business case/capability need

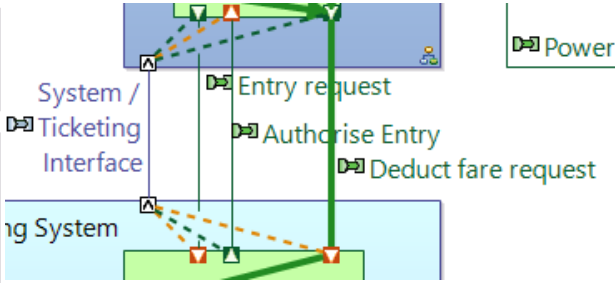


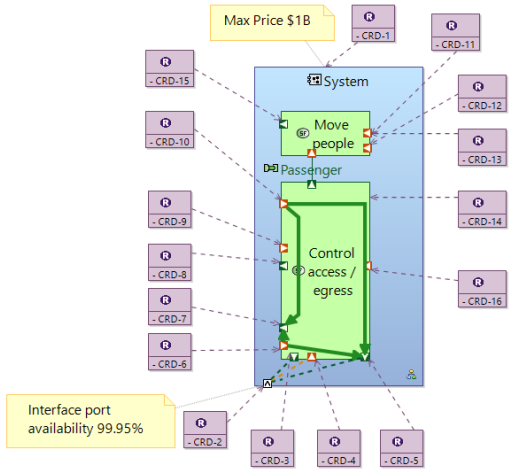


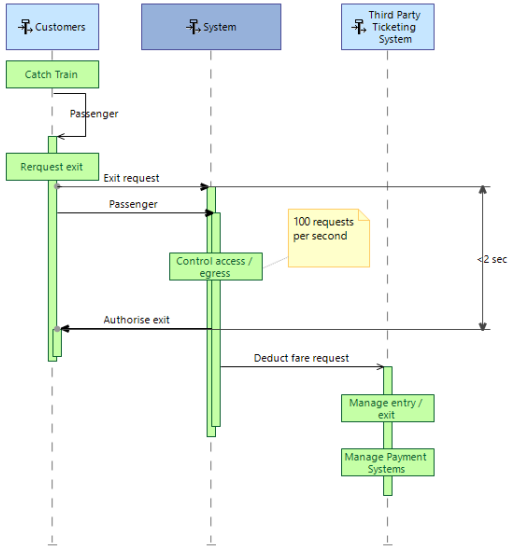
CONCEPTUAL DESIGN ANALYSIS

- Define the scope of the system
- Break down functions to actors/system
- Identify the interfaces
- Perform system scenario analysis
- Allocate performance budgets across actors and system
- Benefits
  - Provides the basis for further MBSE efforts
  - Trace to business case/capability need



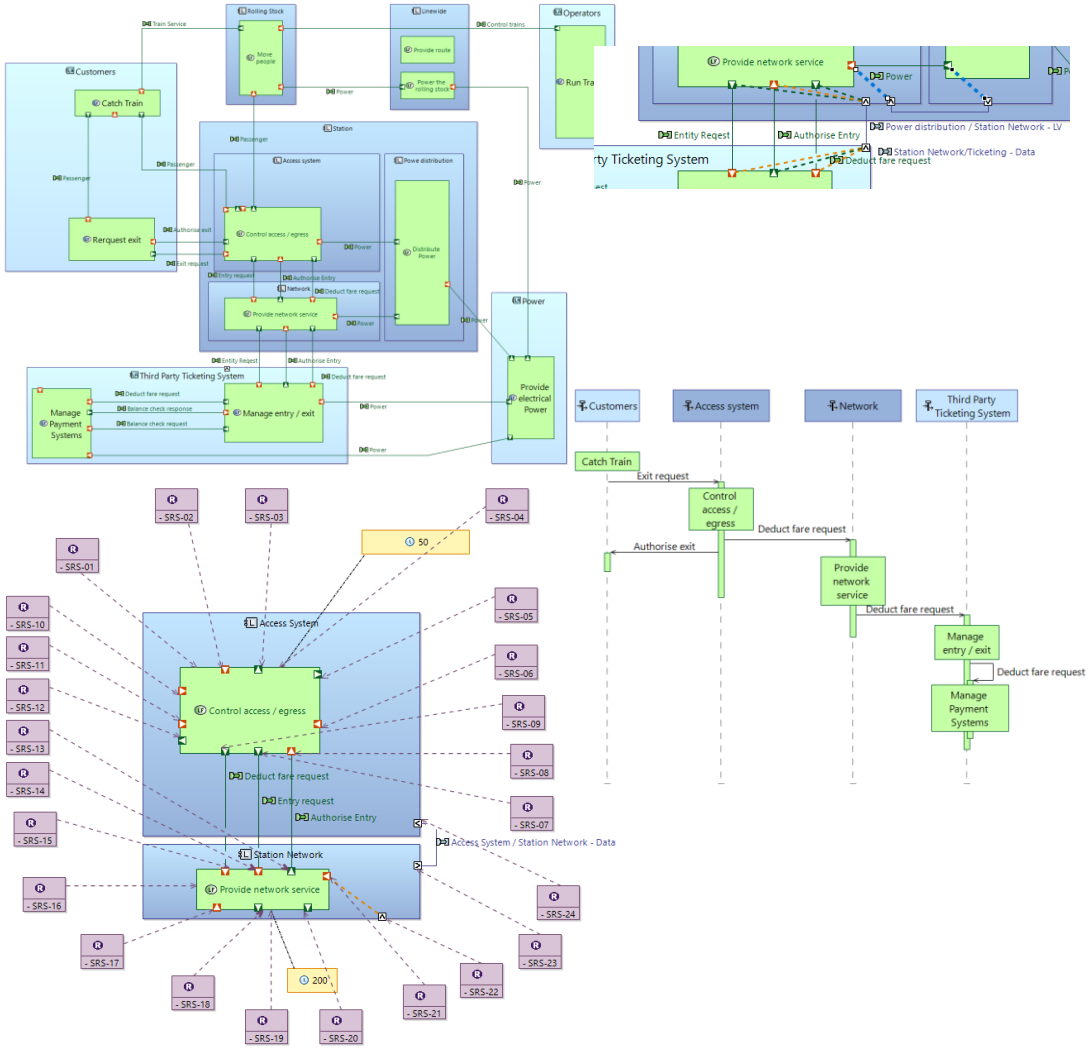






LOGICAL ARCHITECTURE

- Break down the system to components
- Break down system functions to logical functions
- Identify and define interfaces
- Logical architecture scenario analysis
- Establish non-functional budgets across actors and system
- Benefits
  - Provides the basis for further MBSE efforts
  - Trace to business case/capability need



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SUPPLIER BENEFITS

SHARED ACCESSIBILITY

Acknowledgement: Digital Engineering benefits the supplier organisation regardless of the approach taken by the acquisition agency.

- Suppliers' will see potential benefits as early as the tendering phase

- System data passing between acquirer and supplier
  - Shared information "…*in the form of compatible models, allowed for a more effective evaluation of the tender response*"*
  - Better alignment of expectations
  - Reduced likelihood of early project scope change

Enhanced communication
Increased traceability
Reduced errors
Improve consistency
Better accessibility

*Cook S. C., Q. Do, K. Robinson, M. Lay, and M. Neidbala. 2014. "Progress on using MBSE Models as Key Information Artifacts in Project Tendering." Paper presented at the Systems Engineering Test and Evaluation Conference, Adelaide, AU, 28-30 April.

SHARED UNDERSTANDING

- *Current collective understanding!*
- *Key root causes for acquisition project failures is a lack of shared understanding between the acquirer and the supplier**
  - DE leads to current collective understanding
  - DE leads to traceability from context to design
  - DE leads to early understanding of V&V
- Reduce project risk and improve the understanding between supplier and acquirer

*Hallet J., B. Hocking, and M. Vella. 2018. "Modelling Across the Contractual Boundary." Paper presented at the Systems Engineering Test and Evaluation Conference, Sydney, AU, 30 April – 2 May.

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ACQUIRER CHALLENGES

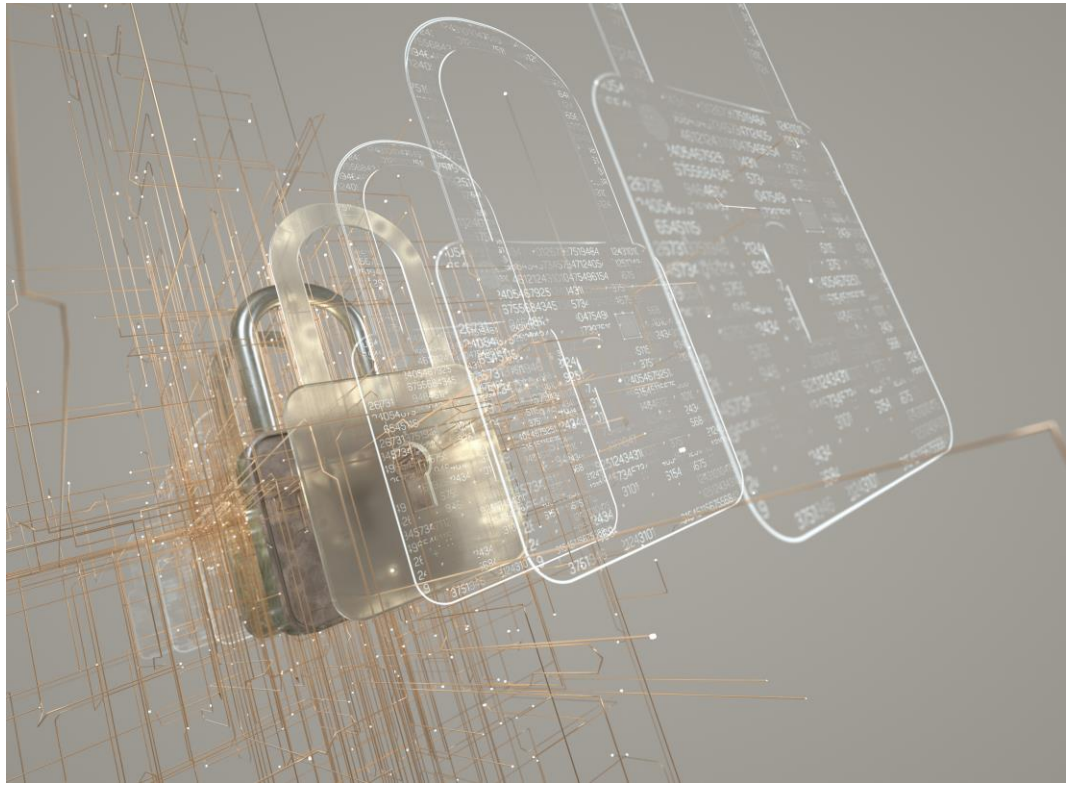
CHALLENGES

- Exist, even for an acquirer with a mature DE capability

- *Single source of truth* (Current collective understanding)
  - Data protection
  - Data standards
  - Maturity of data-centric tools

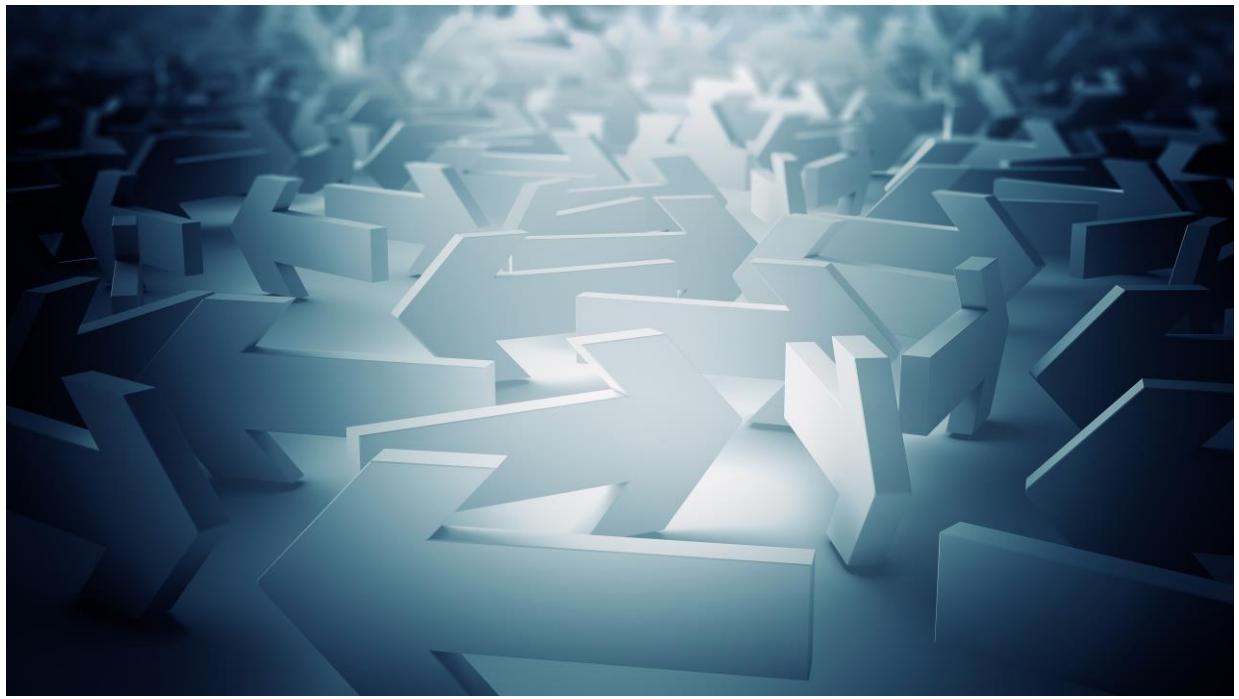
DATA PROTECTION

- Acquisition is a competitive environment
- Mandates careful control/protection of data
  - Whichever way the data flows
- Strict probity requirements
- Containment of supplier data
  - Intellectual property
  - Commercial information



DATA STANDARDS*

- Many different interoperability standards
- Many standards bodies
- …all require alignment

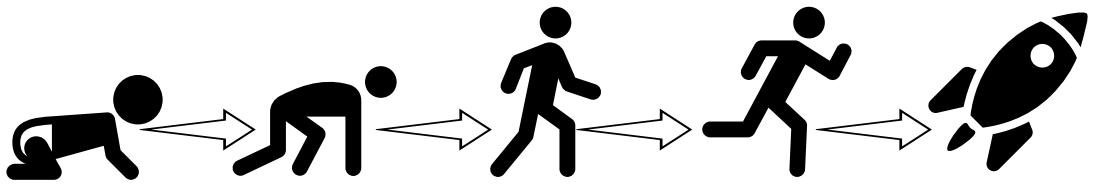


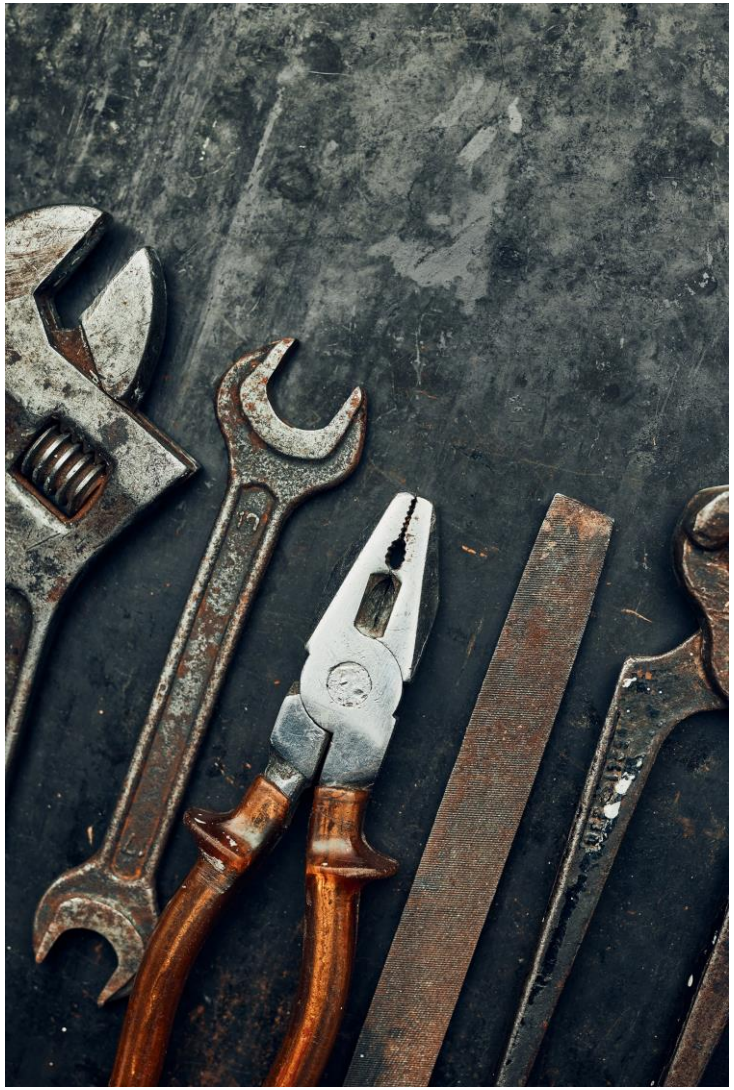
*Williams M., J. Nallon, and W.C. Mendo. 2021. "Where is your Roadmap for implementing MBSE Data Standards?" Paper presented by the INCOSE Tools Integration & Model Lifecycle Management Working Group at the 2021 INCOSE International Workshop, Virtual, 29-31 January

MATURITY OF TOOL SET

- DE reaches across many disciplines
- DE requires a diverse set of tools
- DE applies tools across various phases of the life cycle

- …a long way to go

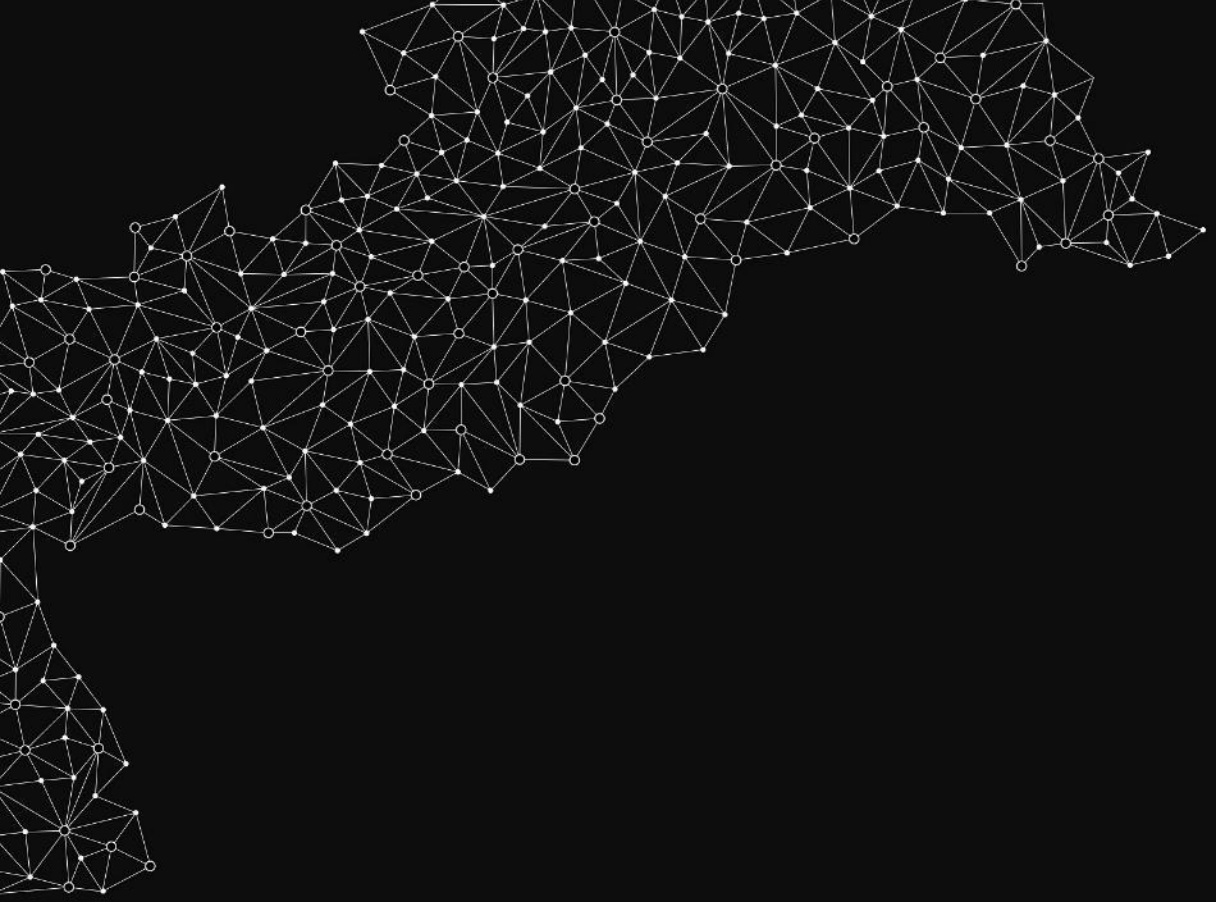




A RECOMMENDATION

- *"...a government-industry collaborative, secure MBSE framework to support diverse tool sets and controlled data exchange to develop stable, clear, affordable, nonconflicting program requirements"*
  - Data protection
  - Data standards
  - Maturity of data-centric tools

*AIA (Aerospace Industries Association) 2016. "Lifecycle Benefits of Collaborative MBSE Use for Early Requirements Development." White Paper, AIA



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SUMMARY

SUMMARY

- Increasing adoption of Digital Engineering

- Opportunity for tremendous benefit when applied early in the life cycle of the engineered system
  - Starts in the Concept Phase
  - Permeates later phases

DRIVING DIGITAL TRANSFORMATION

- Greatest return on investment for Digital Engineering is in the hands of acquisition agencies

- Acquirers need to make the first move
  - Leadership, governance and control
  - Lead by example – adoption of DE

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QUESTIONS AND COMMENTS

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