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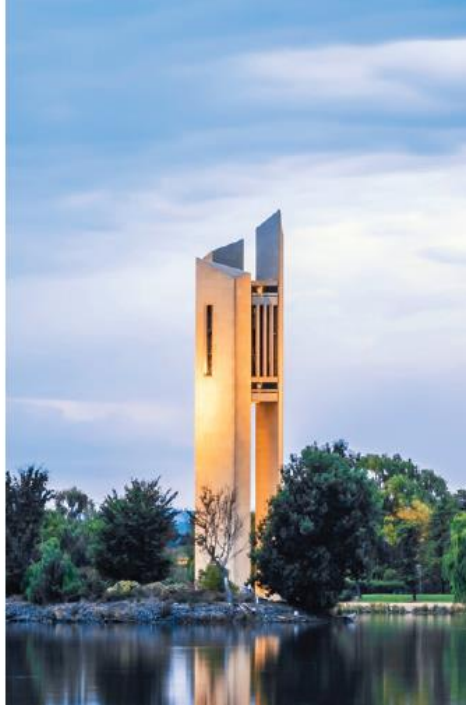
SYSTEMS ENGINEERING TEST AND EVALUATION CONFERENCE 2019

QT Canberra | Australia

29 April – 1 May 2019



SYSTEMS SCIENCE & ENGINEERING FOR A BETTER AUSTRALIA SETE2019.COM.AU

Model-driven Development of Systems Engineering Decision Support System for transport projects: a Survey and an Approach

Pakei Li, Alex Deng, Mahmoud Efatmaneshnik, Bill Parkins

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Summary

- Introduction
- Background from ASEW
- Artefact generation, by phase
  - Concept Exploration & project authorisation
  - Requirements Definition/ Architecture Development
  - Realisation & Transition into Service
  - Operation and Sustainment
- Matrix model and a transportation application
- Further work

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Introduction (based on Abstract)

- The **information** needed to make decisions **varies** through the lifecycle of a system.
- Generation, **Reuse** and Refinement of **artefacts** covering the spectrum of engineering, business and support activities is assessed to identify opportunities to gain the benefits of digitisation and model based engineering.
- This presentation **identifies** and classifies a number of **artefacts related to each life cycle stage**, from conceptual design, to detail design, implementation, support and retirement.
- For each lifecycle stage we **classify the artefacts** into three categories:
  - decision analysis artefacts
  - product technical artefacts and
  - modelling and simulation artefacts.
- We describe the role and importance of each artefact and **the interdependencies between the artefacts**.
- The matrix model presented in this paper is useful for organization of knowledge in model based engineering and creation of libraries for ease of **information retention and reuse.**

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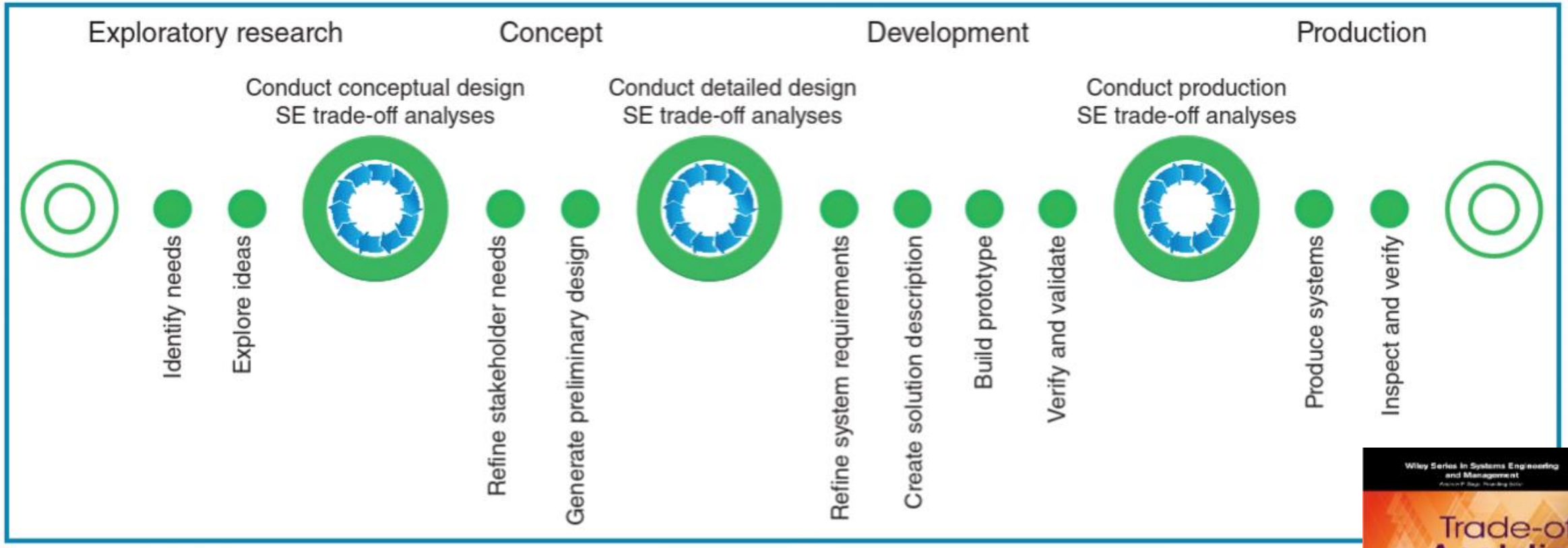
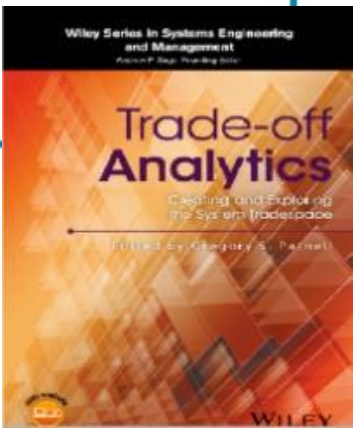
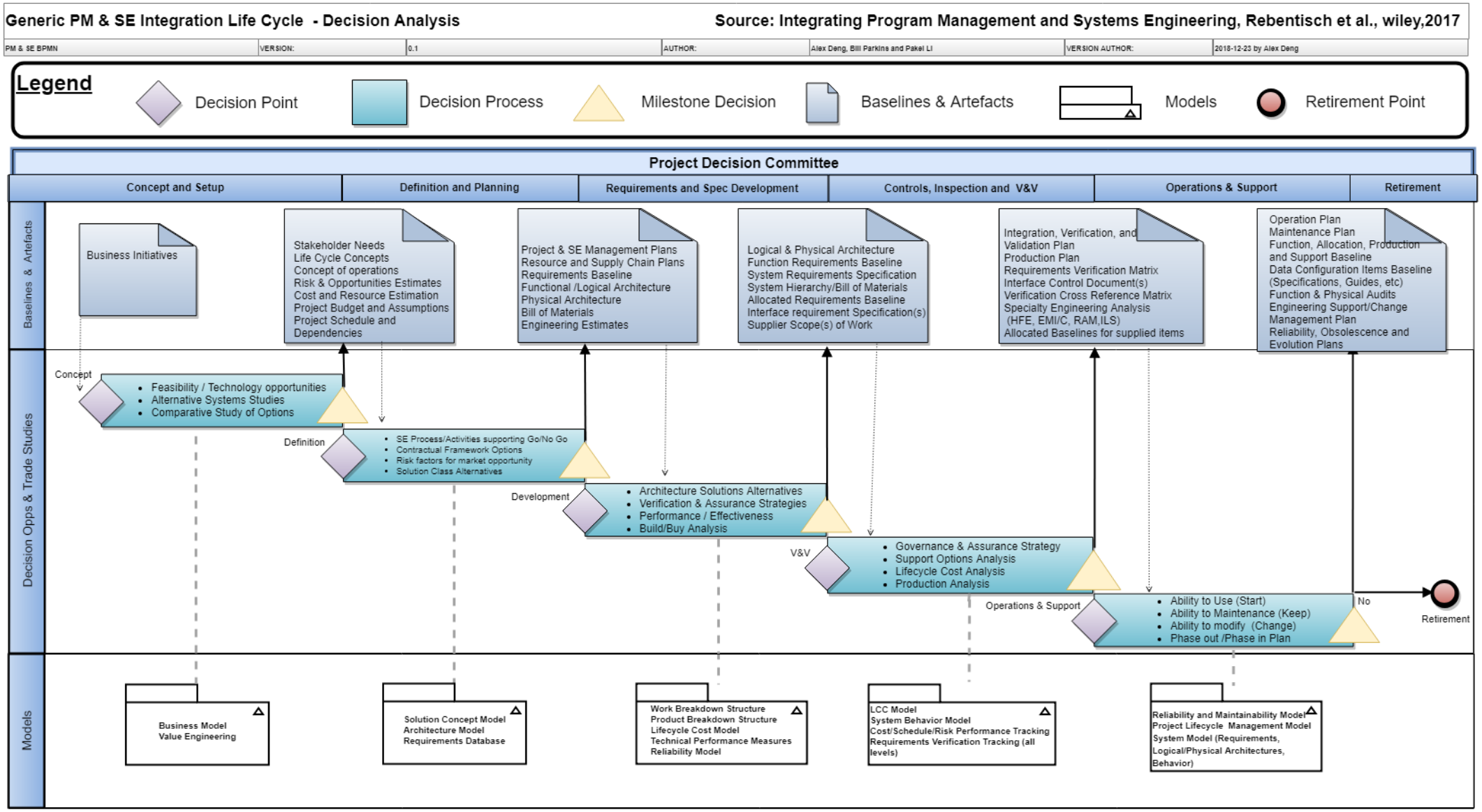
Trade-off Studies in the System Lifecycle





Lifecycle Decision Model



Concept Exploration & Project Authorisation

	Concept and Setup	Definition and Planning
Decision Opps & Trade Studies	Feasibility /Technology Opportunities	SE Process/Activities supporting Go/No Go
	Alternative Systems Studies	Contractual Framework Options
	Comparative Study of Options	Solution Class Alternatives
		Risk factors for market opportunity
Baselines & Artefacts	Stakeholder Needs	Project & SE Management Plans
	Life Cycle Concepts	Resource and Supply Chain Plans
	Concept of operations (ConOps)	Requirements Baseline
	Risks & Opportunity Matrices	Functional/Logical Architecture
	Cost and Resource Estimates	Physical Architecture
	Project Budget and Assumptions	Bill of Materials
	Project Schedule and Dependencies	Engineering Estimates
Models	Value Engineering	Architecture Model
	Business Model	Solution Concept Model
	Lifecycle Cost, Schedule and Risk	Requirements Database

Requirements Definition/ Architecture Development

Decision Opps & Trade Studies	Architecture Solution alternatives
	Measures of Performance/Effectiveness
	Build/Buy analysis
	Verification & Assurance Strategies
Baselines & Artefact	Logical & Physical Architecture
	Functional Requirements Baseline
	System Requirement Specification
	System Hierarchy/Bill of Materials
	Allocated Requirements Baseline
	Interface Requirement Specification(s)
	Supplier Scope(s) of Work
Models	Work Breakdown Structure
	Product Break down Structure
	Lifecycle Cost Model
	Technical Performance Measures
	Reliability Model

Realisation & Transition into Service

Decision Opps & Trade Studies	Governance & Assurance Strategy
	Support options analysis
	Production analysis
	Lifecycle cost analysis
Baselines & Artefact	Integration, Verification, and Validation Plan
	Production Plan
	Requirements Verification Matrix
	Interface Control Document(s)
	Verification Cross Reference Matrix
	Specialty Engineering Analysis (HFE, EMI/C, RAM, ILS)
	Allocated Baselines for supplied items
Models	Cost/Schedule/Risk Performance Tracking
	LCC Model
	Requirements Verification Tracking (all levels)
	System Behaviour Model

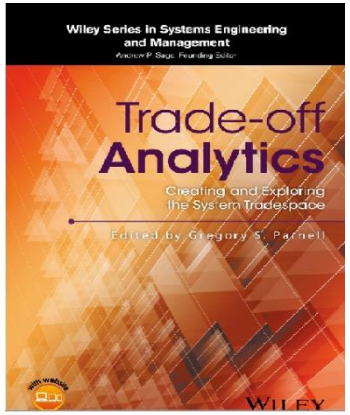
Operation and Sustainment

	Operations & Support
Decision Opps & Trade Studies	Ability to Use (Start)
	Ability to Maintain (Keep)
	Ability to modify (Change)
	Phase-Out/Phase-In Plan
Baselines & Artefact	Function, Allocation, Production and Support Baseline
	Data Configuration Items Baseline (Specifications, Guides, etc)
	Function & Physical Audits
	Operation Plan
	Maintenance Plan
	Engineering Support/Change Management Plan
	Reliability, Obsolescence and Evolution Plans
Models	System Model (Requirements, Logical/Physical Architectures, Behaviour)
	Reliability and Maintainability Models
	Product Lifecycle Management model

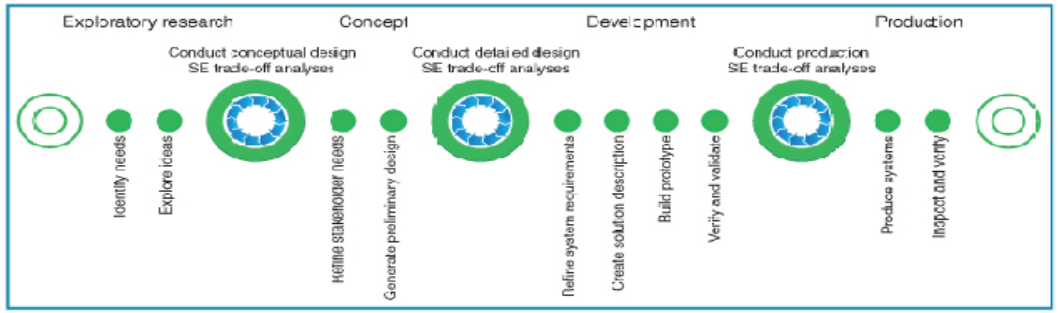
Lifecycle Artefact Matrix

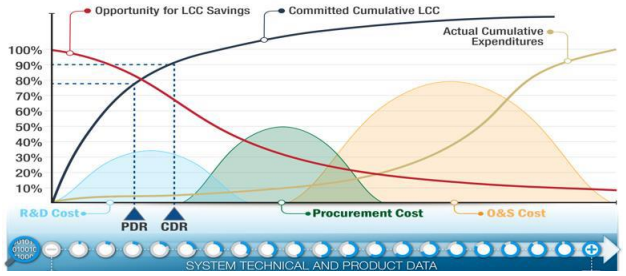
	Concept and Setup	Definition and Planning	Requirements and Specification Development	Control, Inspection and Verification	Operations & Support
Decision Opps & Trade Studies	Feasibility / Technology opportunities	SE Process/Activities supporting Go/No Go	Architecture Solution Alternatives	Governance & Assurance Strategy	Ability to Use (Start)
	Alternative Systems Studies	Contractual Framework Options	Measures of Performance/Effectiveness	Support Options Analysis	Ability to Maintenance (Keep)
	Comparative Study of Options	Solution Class Alternatives	Build/Buy Analysis	Production Analysis	Ability to modify (Change)
		Risk factors for market opportunitiy	Verification & Assurance Strategies	Lifecycle Cost Analysis	Phase-Out / Phase-In Plan
Baselines & Artefact	Stakeholder Needs	Project & SE Management Plans	Logical & Physical Architecture	Integration, Verification, and Validation Plan	Function, Allocation, Production and Support Baseline
	Life Cycle Concepts	Resource and Supply Chain Plans	Function Requirements Baseline	Production Plan	Data Configuration Items Baseline (Specifications, Guides, etc)
	Concept of operations (ConOps)	Requirements Baseline	System Requirements Specification	Requirements Verification Matrix	Function & Physical Audits
	Risks & Opportunities Estimates	Functional /Logical Architecture	System Hierarchy/Bill of Materials	Interface Control Document(s)	Operation Plan
	Cost and Resource Estimation	Physical Architecture	Allocated Requirements Baseline	Verification Cross Reference Matrix	Maintenance Plan
	Project Budget and Assumptions	Bill of Materials	Interface requirement Specification(s)	Specialty Engineering Analysis (HFE, EMI/C, RAM,ILS)	Engineering Support/Change Management Plan
	Project Schedule and Dependencies	Engineering Estimates	Supplier Scope(s) of Work	Allocated Baselines for supplied items	Reliability, Obsolescence and Evolution Plans
Models	Value Engineering	Architecture Model	Work Breakdown Structure	Cost/Schedule/Risk Performance Tracking	System Model (Requirements, Logical/Physical Architectures, Behaviour)
			Product Breakdown Structure	LCC Model	
	Business Model	Solution Concept Model	Lifecycle Cost Model	Requirements Verification Tracking (all levels)	Reliability, and Maintainability Model
			Technical Performance Measures	System Behaviour Model	
	Life Cost, Schedule and Risk	Requirements Database	Reliability Model		Product Lifecycle Management Model

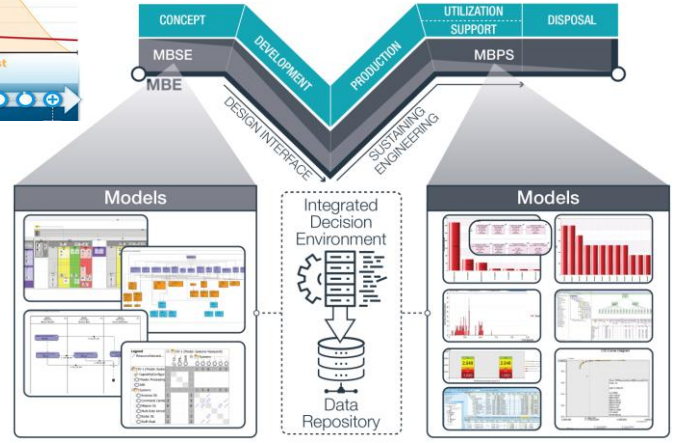
Decision Analysis and Lifecycle Workshops



- Tutorials and workshops at Australian Systems Engineering Workshops (ASEW) in 2017 and 2018
- Using products and concepts generated at INCOSE Technical Working Groups, principally on Decision Analysis and Product Lifecycle Engineering







ASEW 2018 Objectives

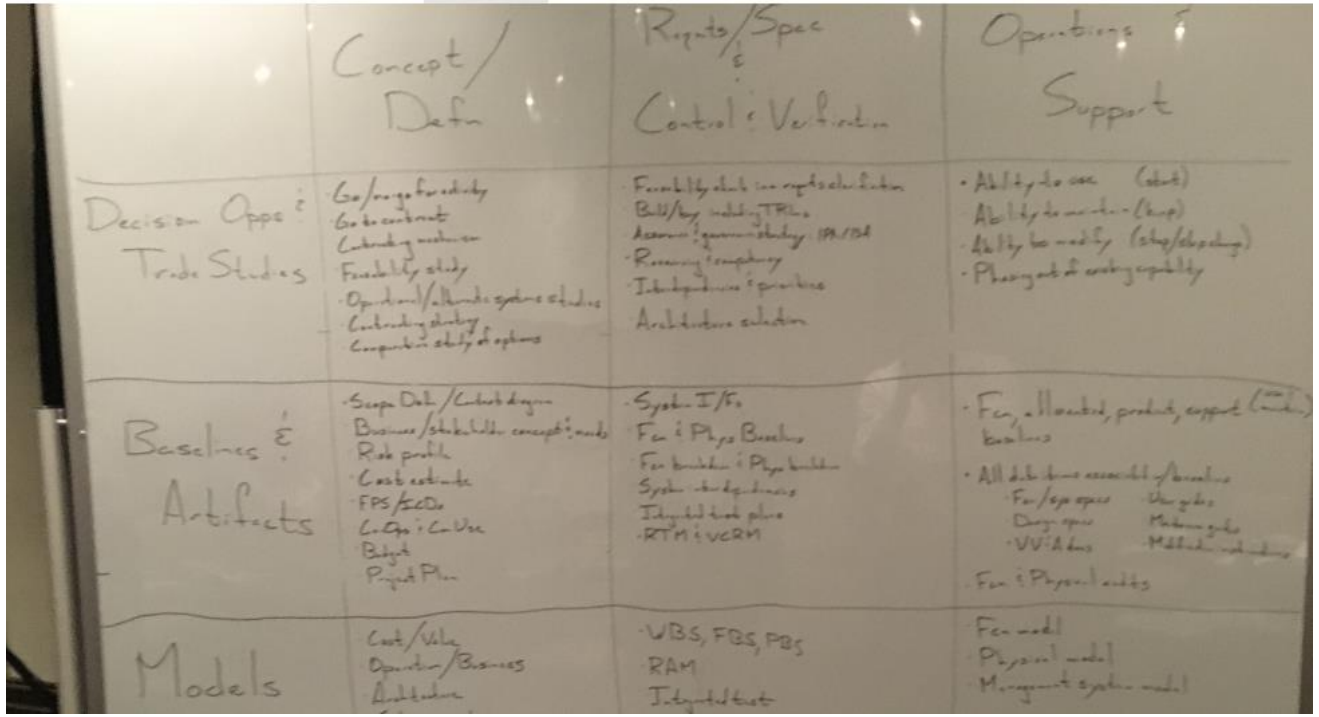
Aim was to explore reuse of trade-off analyses through the lifecycle

- For significant phases
  - List decision opportunities and trade studies
  - Identify baselines & artefacts
  - Suggest system models used

Continue to develop concepts and contribute to :

❖SETE 2019 as an Industry Presentation

❖AOSEC 2019, Bangalore in October as a SESA paper



Transportation application

- Transport of NSW has developed a process by which go/no-go decision points, and associated assurance artefacts/activities, are defined for use during complex programs and projects
- The process requires the definition of the Significance of a program / project which is categorised by a set of criterion into Major, Moderate and Minor categorisation. In TfNSW, the primary driver for the categorisation is the level of safety change as a result of the program / project.
- to define required level of assurance activities throughout the lifecycle.
- Each level of Significance categorisation would then define the Go/No-go Decision Gates and equivalent artefacts / activities required to progress past the gates.

Artefact Framework Example

Initiation Stage

Gate Number	Document	Scope	Provide for SCARD Significant	Provide for SCARD Moderate	Provide for SCARD Minor	Remarks	ST Process Standard	Document development standard
Gate 0	Preliminary Scope of work	Support	YES	YES	YES		ST PCM Manual MWD-PRSM-MN-000	
Gate 0	Preliminary schedule	Support	YES	YES	OPTIONAL		ST PCM Manual MWD-PRSM-MN-000	
Gate 0	SCARD	Support	YES	YES	YES		ST PCM Manual MWD-PRSM-MN-000	ST SMS-07-FM-4049
Gate 0	Business Case	Support	YES	YES	YES		ST PCM Manual MWD-PRSM-MN-000	
Gate 0	Assurance and Governance Plan	Support	YES	OPTIONAL	NO	SCARD significant or important only	ST SMS and TfNSW ASA T MU AM 04002 GU	TS 10752
Gate 0	System safety analysis	Support	YES	YES	OPTIONAL		ST SMS	SMS-07-GD-3084
Gate 0	Life cycle costing outcomes	Support	YES	OPTIONAL	NO		TfNSW ASA	T MU AM 01001 ST
Gate 0	Project Initiation Document	Support	YES	YES	OPTIONAL		ST PCM Manual MWD-PRSM-MN-000	PID form
Gate 0	CCR Gate 0 submission	Support	YES	YES	OPTIONAL		ST PCM Manual MWD-PRSM-MN-000	
Gate 0	Operational Concept Document	Produce	YES	YES	OPTIONAL	Tier 1 and 2 projects as categorized in PCM Manual		T MU AM 06006 ST
Gate 0	Maintenance Concept Document	Produce	YES	YES	OPTIONAL	Tier 1 and 2 projects as categorized in PCM Manual		T MU AM 06009 ST
Gate 0	Human Factors Work Determination	Produce	YES	OPTIONAL	NO	SCARD significant or important only	ST SMS	ST SMS-07-FM-4142
Gate 0	Reliability, Availability and Maintainability determination	Produce	YES	YES	OPTIONAL		ST BMS	T MU AM 06002 GU
Gate 0	Project Risk Register	Produce	YES	YES	YES		ST PCM Manual MWD-PRSM-MN-000	

Project Artefacts Example

Project LC phase ID	System LC phase ID	Activity ID	Artefact type - output	Artefact description	Estimated effort Agreed [h]	Agreed effort [h]
P2	S2	EART	SPEC02	Business Requirements Specification		
P2	S2	EART	RECOX2	Judgement of Significance		
P2	S2	EART	PLAN04	(System) Engineering Management Plan		
P2	S2	EART	PLAN04	Verification and Validation Plan		
P2	S2	EART	DIAGX0	System functional architecture		
P2	S2	EART	REGRX4	Requirements Allocation and Traceability Matrix (RATM)		
P2	S2	EART	REPT13	RAMS assessment		
P2	S2	EART	REPT13	System Definiton Review		
P3	S3	EASS	DIAGX0	Physical Architecture		
P3	S3	EASS	REGRX4	RATM (update)		
P3	S3	EASS	REPT13	RAMS (update)		
P3	S3	EASS	SPEC02	System Requirements Specification		
P3	S4	EART	REGRX3	Assurance Comments Register (update)		

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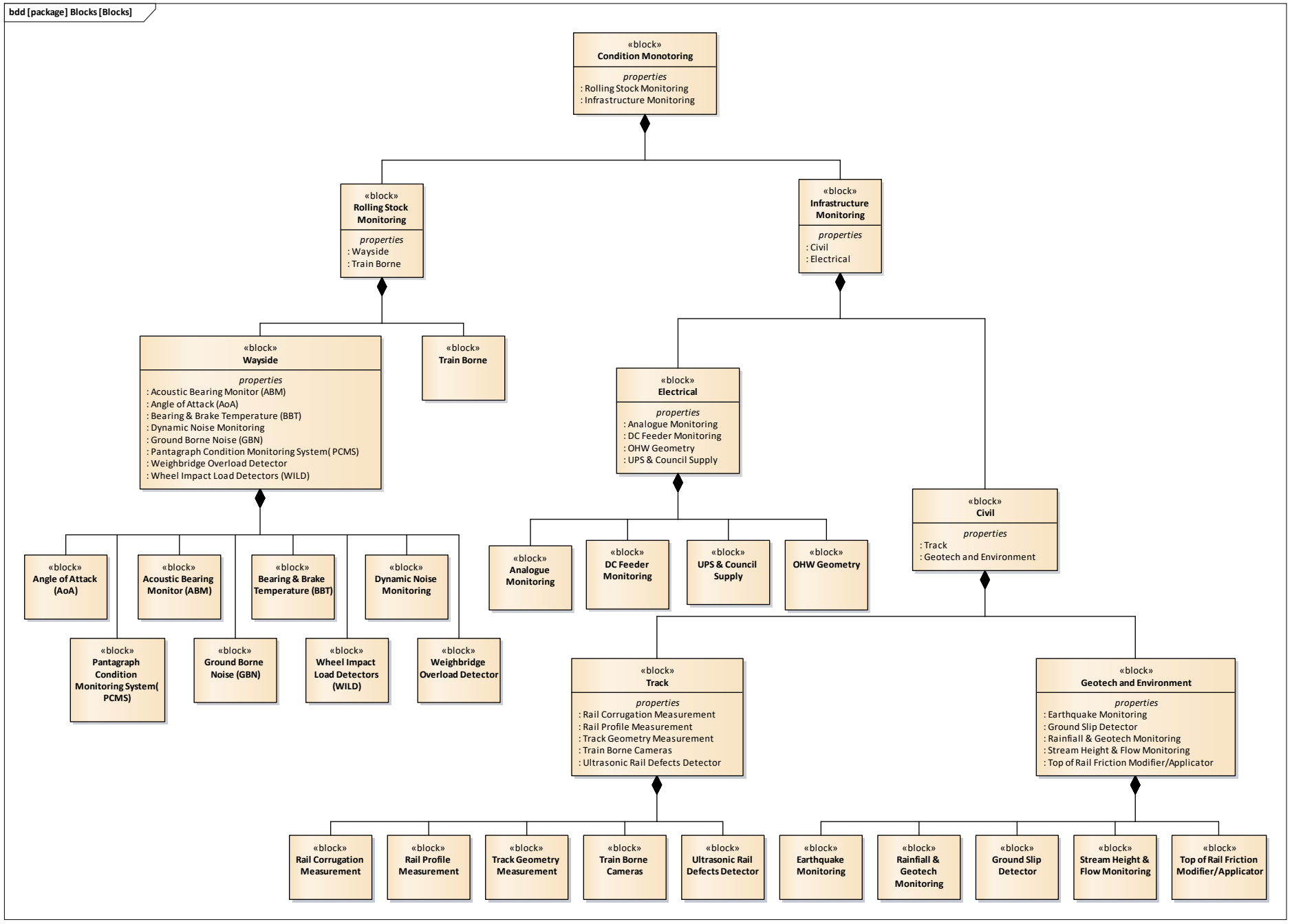
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properties
: Rolling Stock Monitoring
: Infrastructure Monitoring
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properties
: Wayside
: Train Borne
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Infrastructure Monitoring
properties
: Civil
: Electrical
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Wayside
properties
: Acoustic Bearing Monitor (ABM)
: Angle of Attack (AoA)
: Bearing & Brake Temperature (BBT)
: Dynamic Noise Monitoring
: Ground Borne Noise (GBN)
: Pantagraph Condition Monitoring System(PCMS)
: Weighbridge Overload Detector
: Wheel Impact Load Detectors (WILD)
«block»
Train Borne
«block»
Electrical
properties
: Analogue Monitoring
: DC Feeder Monitoring
: OHW Geometry
: UPS & Council Supply
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Civil
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: Track
: Geotech and Environment
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Angle of Attack (AoA)
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Acoustic Bearing Monitor (ABM)
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Bearing & Brake Temperature (BBT)
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Dynamic Noise Monitoring
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Wheel Impact Load Detectors (WILD)
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Analogue Monitoring
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OHW Geometry
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Track
properties
: Rail Corrugation Measurement
: Rail Profile Measurement
: Track Geometry Measurement
: Train Borne Cameras
: Ultrasonic Rail Defects Detector
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Geotech and Environment
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: Earthquake Monitoring
: Ground Slip Detector
: Rainfall & Geotech Monitoring
: Stream Height & Flow Monitoring
: Top of Rail Friction Modifier/Applicator
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Ground Slip Detector
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Stream Height & Flow Monitoring
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Top of Rail Friction Modifier/Applicator

Further Work

- Develop a technical paper for INCOSE Asia-Oceania SE Conference in Bangalore (October 2019)
- Define a model-driven framework which shall provide a Systems Engineering decision supporting toolset for complex programs / projects.
- Develop an optimal sequence for artefact generation, and model the artefact relationships.
- Further develop concepts at ASEW 2019