27th annual INCOSE international symposium

Adelaide, Australia

July 15 - 20, 2017

Using the System-of-Systems Engineering (SoSE) Principles

Jaci Pratt, Defence Science & Technology Group &
Stephen Cook, University of Adelaide

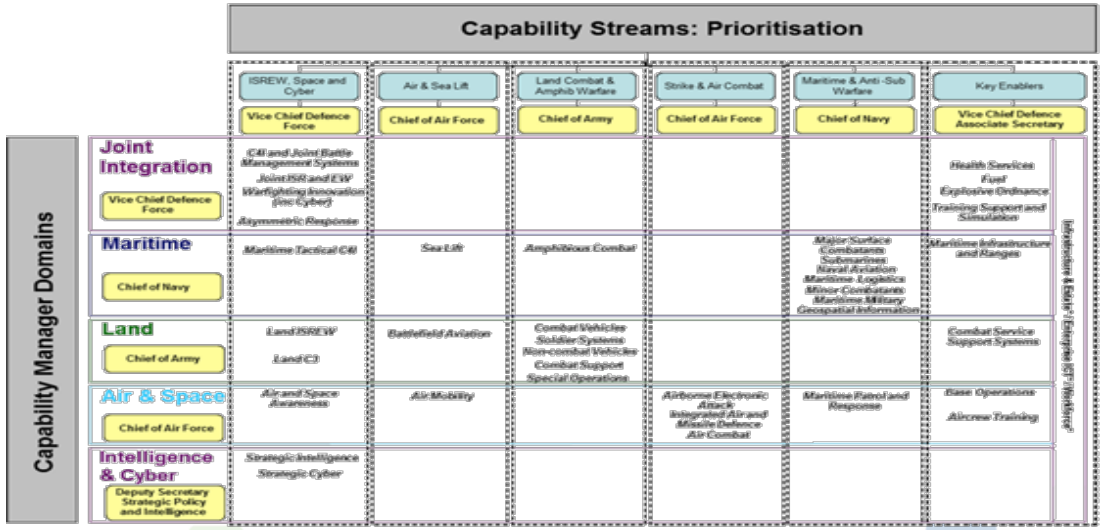
www.incose.org/symp2017

Introduction

- Australian Defence Changes:
  - First Principles Review, Defence White Paper, Industry Policy, Integrated Investment Plan
  - Increase focus at beginning of CLC to achieve truly joint capability => design and integration at capability level (> Projects)
  - Portfolio of 40 Programs (acquisition projects mapped)

- First Principles Review reforms:
  - Need for guidance to practitioners on how to implement at the Capability/Program level

- SoSE can assist …
  need for guidance & principles

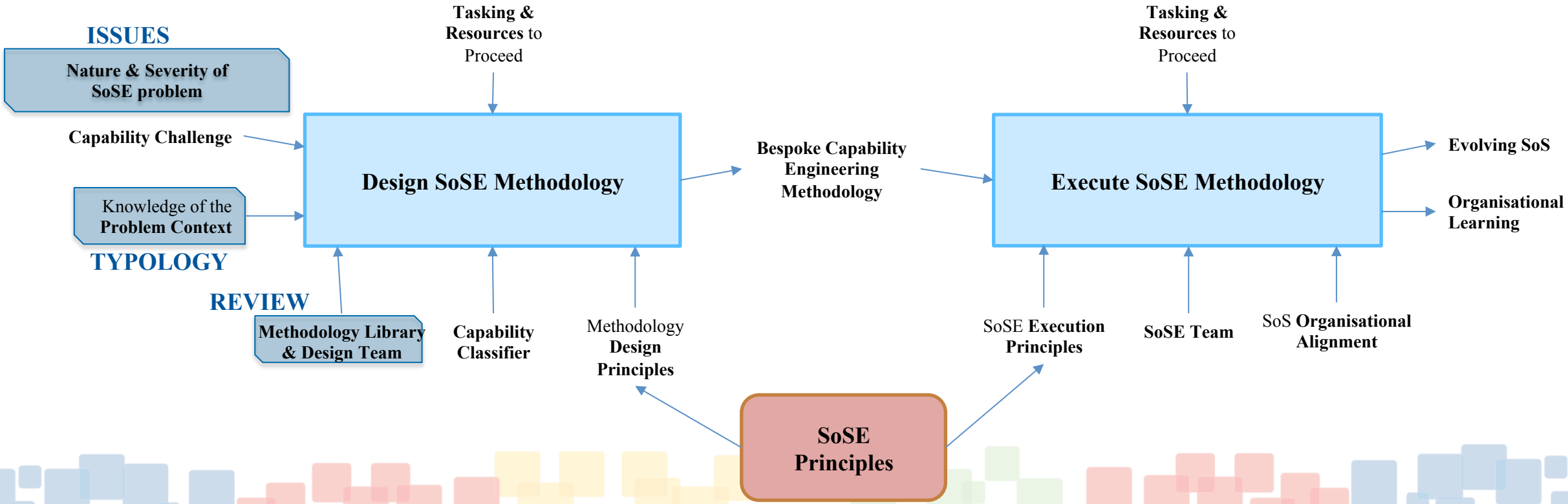


SoS Engineering is Different

- SoS Engineering ≠ Traditional Systems Engineering
- SoS Engineering is:
  - Concerned with delivering outcomes not equipment
  - Inherently socio-technical
  - Strong on ‘architecting’; less on structured approaches
  - Coordinating the efforts of number of independent CS
  - Achieved through exerting leadership and influence
  - Adaptive & steers continual evolution of capability and CS
    - i.e NOT generic, rigid processes or process improvement fwks
- Successful SoSE requires thoughtful approach design

Methodology Design as a Design Process

- A SoSE methodology can be designed similarly to the design of a system
- The methodology is designed and then it enters an operational phase
- The design process needs the components shown below (IDEF0)
- **SoSE Principles are a key element for both design and execution**

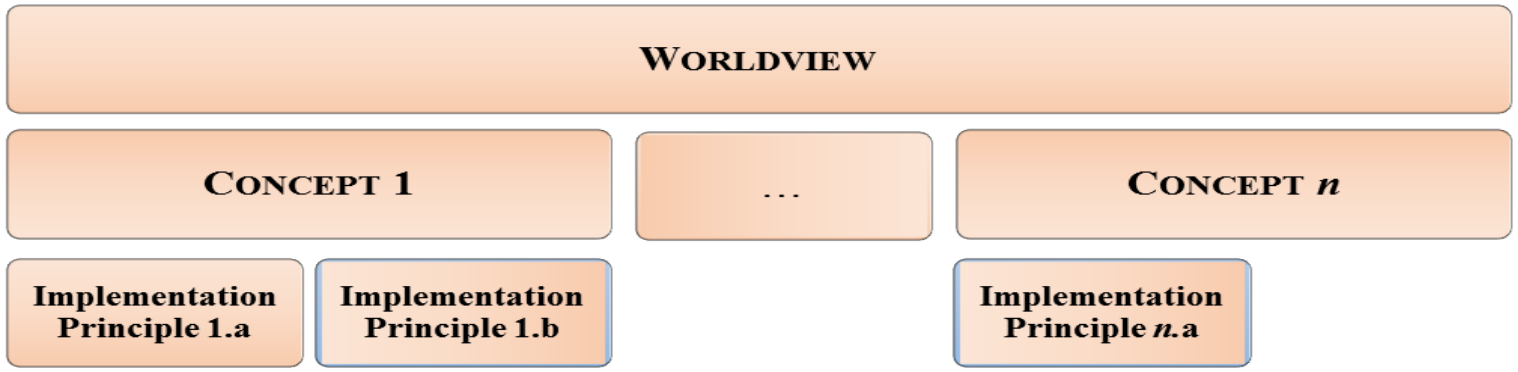


The SoSE Principles Hierarchy

Aim: Codify the principles for successful SoSE practice

- Provide a framework to direct and focus, based on 'purpose'
- Three tiered framework:

  Worldview – Concepts – Implementation Principles
- Approach taken:
  - Two rounds of literature review and thematic analysis; Augmented by interviews/ discussions with SoSE practitioners => two key papers

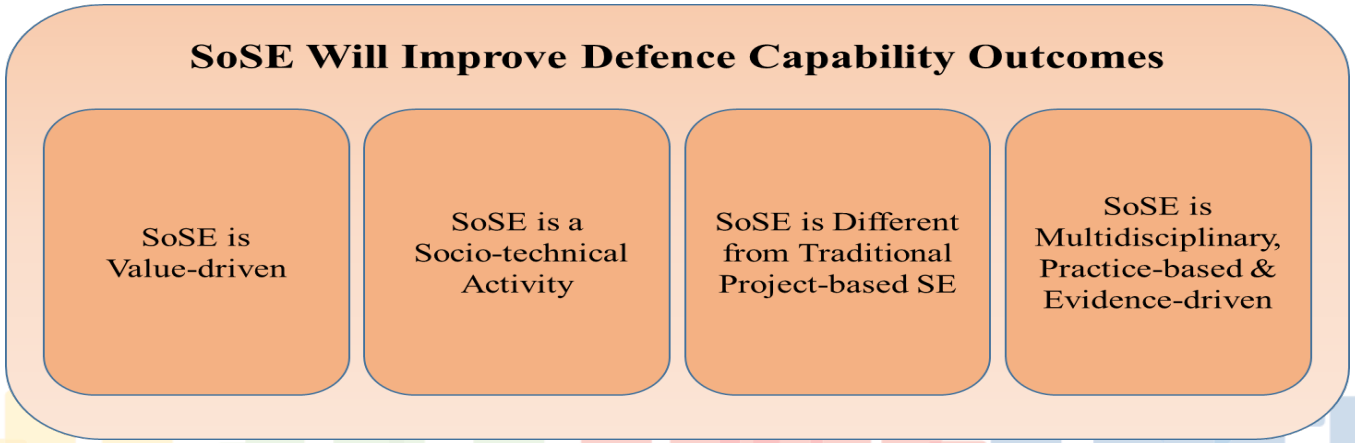


Worldview (Weltanschauung)

- Established a worldview that states the philosophical position and its four pillars of belief

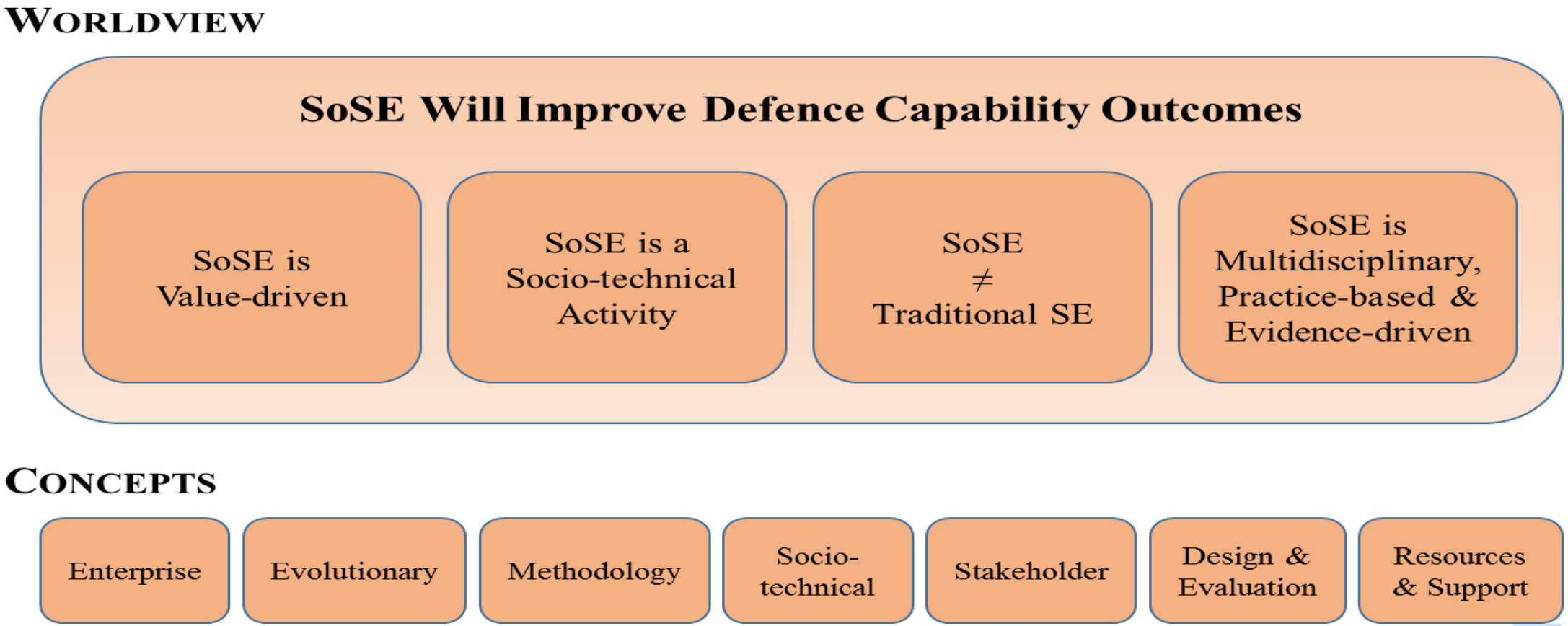
SoSE will improve capability (complex system) outcomes

- SoSE is value-driven
- SoSE is socio-technical
- SoSE is NOT traditional project-based SE
- SoSE is multidisciplinary, practice-based and evidence driven



Concepts

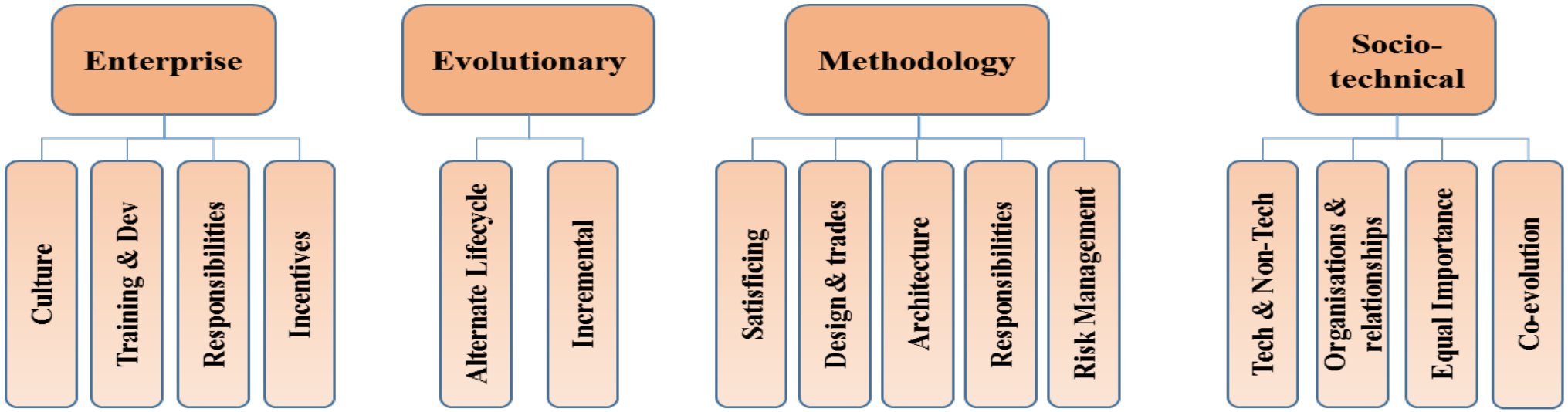
- Principles grouped under seven concepts

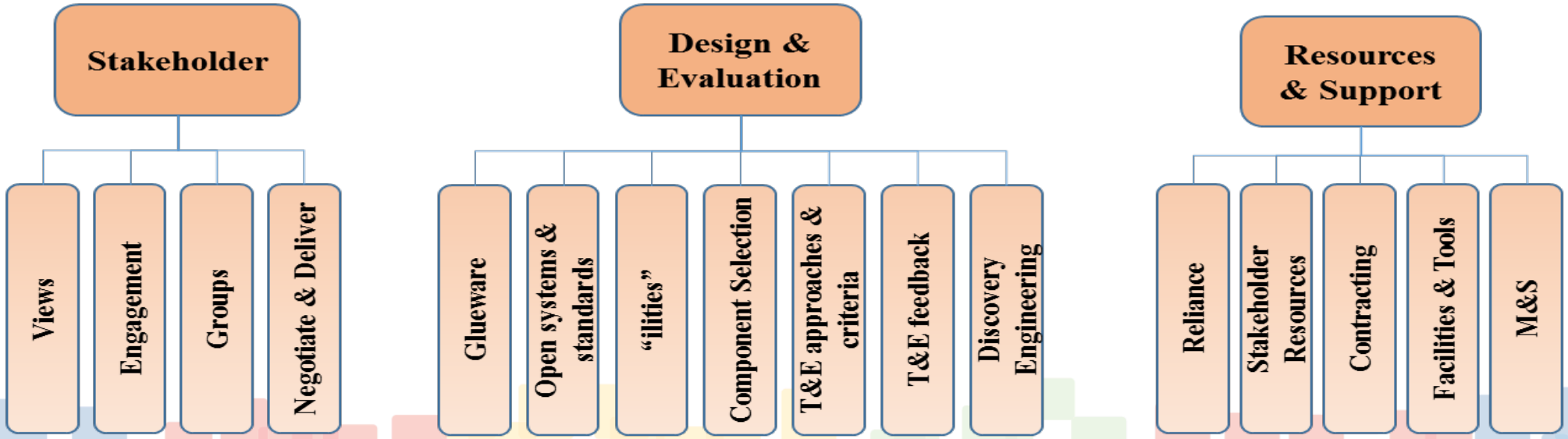


Concepts

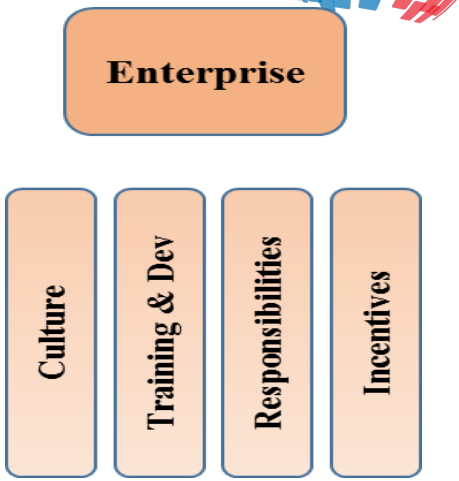
- Based around the guiding philosophy of the worldview
- Provide conceptual direction
- Seven core concept groupings derived from 26 principles
  - SoSE must address **enterprise-level considerations**
  - SoSE is an incremental, **evolutionary** methodology
  - SoSE is a **meta-methodology** and must be tailored to the specific SoS, environment and mission.
  - SoSE is **socio-technical** and human-based activity
  - SoSE must include **stakeholders** & work within their values
  - **Design** practices must be blended top-down & bottom-up supported by **evidence-based** assessments
  - **Resources** and governance structures must be agile, collaborative, flexible and innovative

Implementation Level





Enterprise Principles

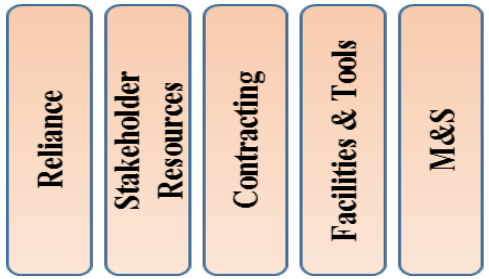


The enterprise must embrace SoSE

1. Create and maintain a SoSE-aware culture. i.e. consider & balance both SoS and CS needs; use SoSE guidance.
2. Structure training, development and management specifically for SoSE (≠ SE).
3. Be fundamentally responsible for, & provide key services to, facilitate SoSE i.e. architecting, governance, tools, IM and research.
4. Utilize incentives to reward and instill good SoSE behavior => identification of the attributes of good SoSE behavior across the organization.

Resources & Support Principles

Resources (people, funding and facilities) and governance structures must be agile, collaborative, flexible & innovative



1. SoSE team is small and achieves much of its mission through CS project offices. This requires project office buy-in and consensus-based co-ordination.
2. Achieve SoSE program robustness through securing resource support across the stakeholder network.
3. Flexible and innovative contracting mechanisms are required that align with the SoSE methodology, context and SoS evolutions such as formal and/or informal CS-SoS agreements.
4. SoSE facilities, infrastructure & tools must be more collaborative, federated, interoperable, and aligned to the methodology. Data consistency and knowledge management are essential.
5. SoS-focused Modelling & Simulation (M&S) is essential for analysis and assessment to support planning, trade decisions, and evaluation.

Substantiation of the Principles

- Multi-level subjective and evidence-based process to confirm the framework, principles and their usefulness nature
- Three key framework assurance components:
  - Coverage of the framework;
  - Applicability of the framework; and
  - Utility of the framework.
- Method:
  - Assessment of implementation principles against:
    - Identified SoS challenges;
    - Capability Inputs (i.e. DOTMLPF; TEPIDOIL; FIC);
    - Key SE / SoSE parameters (i.e. life cycle phases, scale/scope); and
    - Key stakeholder roles including Systems and SoS Engineering roles.
  - Principles Hierarchy Review by practitioners; and
  - Application of the principles and hierarchy (case studies)

Coverage Assessment

- Show the Principles Hierarchy covers SoSE space
- Assess coverage of Principles across two key issues surveys
  - Pain Points & Return to Sleepless Nights
  - Evaluate current issue lists against implementation principles and aggregated to concepts
- Subjective Assessment with Likert-like scale
  - ***"If this principle was applied, how much reduction would be seen in the issue as described?"***
    - 0 - reduced minimally or not at all
    - 1 - reduced to a moderate level
    - 2 - reduced markedly
  - Magnitude of aggregated concept assessment implied a higher relevance and coverage

Data Capture via Excel

- Aggregate assessment of implementation principles up to concepts
- Combine individual responses to form overall assessment

Issue-PP Name	Detail	Map - Concepts							Map - Imp Princ			
		4	2	5	4	4	7	5				
	QUESTION: *If this principle was applied, the issue as described would be:* *0 - reduced minimally or not at all; (still requires significant management)* *1 - reduced to a moderate level; (requiring some to low management)* *2 - reduced markedly; (requires minimal to no management)*	Enterprise (4)	Evolutionary (2)	Methodology (5)	Socio-technical (4)	Stakeholder (4)	Design & Evaluation (7)	Resources & Support (5)	SoSE-aware culture	SoS Training, dev & wkfce mgmt	SoSE Responsibilities & services	Incentives
SoS Authorities	authority conflicts & arbitration btwn CS-SoS organizational structure, funding and collaboration	7	1	5	3	6	6	7	2	1	2	2
Leadership of SoS SE	lack of structured control needs different leadership for technical, organizational and stakeholder management	6	1	3	5	7	6	7	2	2	1	1
Constituent Systems	issues with coordination and management of multiple independent constituent systems in SoS risks due to different data, information, technical, processes, cultures, working practices btwn systems & SoS	5	3	8	5	4	8	8	1	1	2	1
Capabilities & Requirements	CS have own reqts, so SoS needs may not be consistent with CS needs SoS reqts are not able to be developed at same detail (more abstraction, broader & non-material)	5	3	6	4	5	10	5	1	1	2	1
Autonomy, Interdependencies & Emergence	SoS produce unexpected behaviour SoS relationships are poorly understood & difficult to analyse Lack analytical tools/methods for SoS	5	2	4	2	2	7	6	2	1	1	1
Testing, Validation and Learning	CS asynch dev cycles mean testing difficult end2end testing of SoS difficult Assess SoS perf thru actual operation	2	2	4	2	2	9	5	1	1	1	1
SoS Principles and Thinking Skills	lack of formalised processes, and principles of success	5	2	5	2	2	7	4	1	2	2	1

Coverage – Pain Points Issues

	Enterprise	Evolutionary	Methodology	Socio-technical	Stakeholder	Design & Evaluation	Resources & Support
SoS Authorities	✓		?	?	✓	?	✓
Leadership	✓			✓	✓	?	✓
Constituent Systems	✓	✓	✓	✓	?	✓	✓
Capabilities & Requirements	✓	✓	✓	?	✓	✓	?
Autonomy, Interdependencies & Emergence	✓	?	?			?	✓
Testing, Validation & Learning	?	?	?			✓	?
SoS Principles & Thinking	✓	?	?			?	?

Coverage – Return to Sleepless Nights Issues

	Enterprise	Evolutionary	Methodology	Socio-technical	Stakeholder	Design & Evaluation	Resources & Support
Technical Challenges (SE to SoS)	✓	✓	✓		?	✓	✓
SoS Programmatic Considerations	✓	?	?		✓	✓	✓
SoSE Workforce Development	✓						?
SoS Methods, Processes & Tools	?	✓	✓	?	?	✓	✓
SoS Considerations for Systems	✓	?	?	?	?	?	?
Standards						?	
SoSE Mindset/Culture	✓	?	?		✓		?
T&E	?	?	?		?	✓	✓
SoS Social/Organizational Aspects	✓	?	?	✓	✓	?	✓

Coverage Insights

- Principles Hierarchy:
  - Provides coverage across the PP & RTSN issues
    => Implementation principles / concepts provide a cross-capability solution space to deal with SoS problems
  - Enterprise concept was a key influencer across both
  - Some issue areas not strongly affected by implementation principles => weakness in detail or span.
- Utilising these principles should significantly impact SoS issue resolution
- Further development and substantiation would be of value

Who should use the Principles?

Principles were structured to speak to different groups

- Concepts level and Enterprise principles
  => Senior Managers and Users
- Design & Evaluation / Resources & Support principles
  => Project technical staff
- SoSE team have a broader purview
  => Methodology, Stakeholders, and Socio-technical concepts and implementation principles

Utility Assessment

- Principles Hierarchy useful for:
  - Supporting practitioners on identification of methodologies
  - Forming a paradigm for thinking, behaviour, decision & action
- Hierarchy therefore must:
  - Be clear, simple, unambiguous, easily understood and implementable
  - "Prioritise" knowledge required by stakeholders
- Evaluate utility of principles via:
  - Subjective assessment of the need for knowledge of the principles by specific SE/ SoSE roles and functions
  - ***"As a Systems Engineer for a Constituent System within a SoS, does this Implementation Principle have a high impact on my role?"***
- Initial assessment against Sheard's SE roles

Utility – CS SE Roles

	Enterprise	Evolutionary	Methodology	Socio-technical	Stakeholder	Design & Evaluation	Resources & Support
Requirements Owner	✓		✓		✓	✓	
System Designer	✓	✓	✓			✓	
System Analyst			✓				✓
Validation/Verification Engineer	✓				✓	✓	✓
Logistics/Operations Engineer				✓		✓	
Systems Integrator (Glue Among Subsystems)	✓	✓	✓			✓	✓
Customer Interface	✓			✓	✓		
Technical Manager				✓			✓
Information Manager			✓				
Process Engineer	✓						
Coordinator	✓			✓	✓		
Classified Ads SE							✓

Utility Insights

- Key insights were:
  - Certain roles require greater understanding of principles (Requirements Owner, Systems Designer, V&V Engineer and Systems Integrator)
  - Systems Integrator role (as expected) had greatest need for knowledge of the Implementation Principles
  - Several roles had only one concept area of high impact (Information Manager, Process Engineer and Classified Ads SE)
  - Principles framework divided the SoSE knowledge needed by CS SEs
  - Many interdependencies exist between the principles

Next Steps …

- Coverage & Utility:
  - Identify other issues lists and roles for assessment
  - Extend the assessment to other experts/practitioners
  - Extend coverage to capability inputs, key SE / SoSE parameters, etc.
- Applicability:
  - Develop feedback surveys
  - Select practitioners and specialists of varying experience
  - Use the principles and hierarchy in case studies
- Principles:
  - Combine/contrast to other principles work worldwide
  - Extend / Increase detail for implementation principles
  - Embed principles into practices

27th annual INCOSE international symposium

Adelaide, Australia

July 15 - 20, 2017

ENGINEERS AUSTRALIA

SESA

Questions?

Australian Government

Department of Defence

Defence Science and Technology Group

www.incose.org/symp2017