28th Annual INCOSE international symposium

Washington, DC, USA

July 7 - 12, 2018

Session 7.5.1 – Presented by Regina Griego and Patrick Godfrey

A fresh look at Systems Engineering – what is it, how should it work?

www.incose.org/symp2018

Background and context for Fellows Initiative

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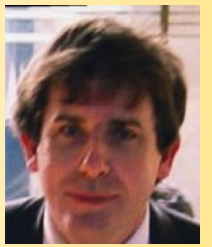


Daniel Krob

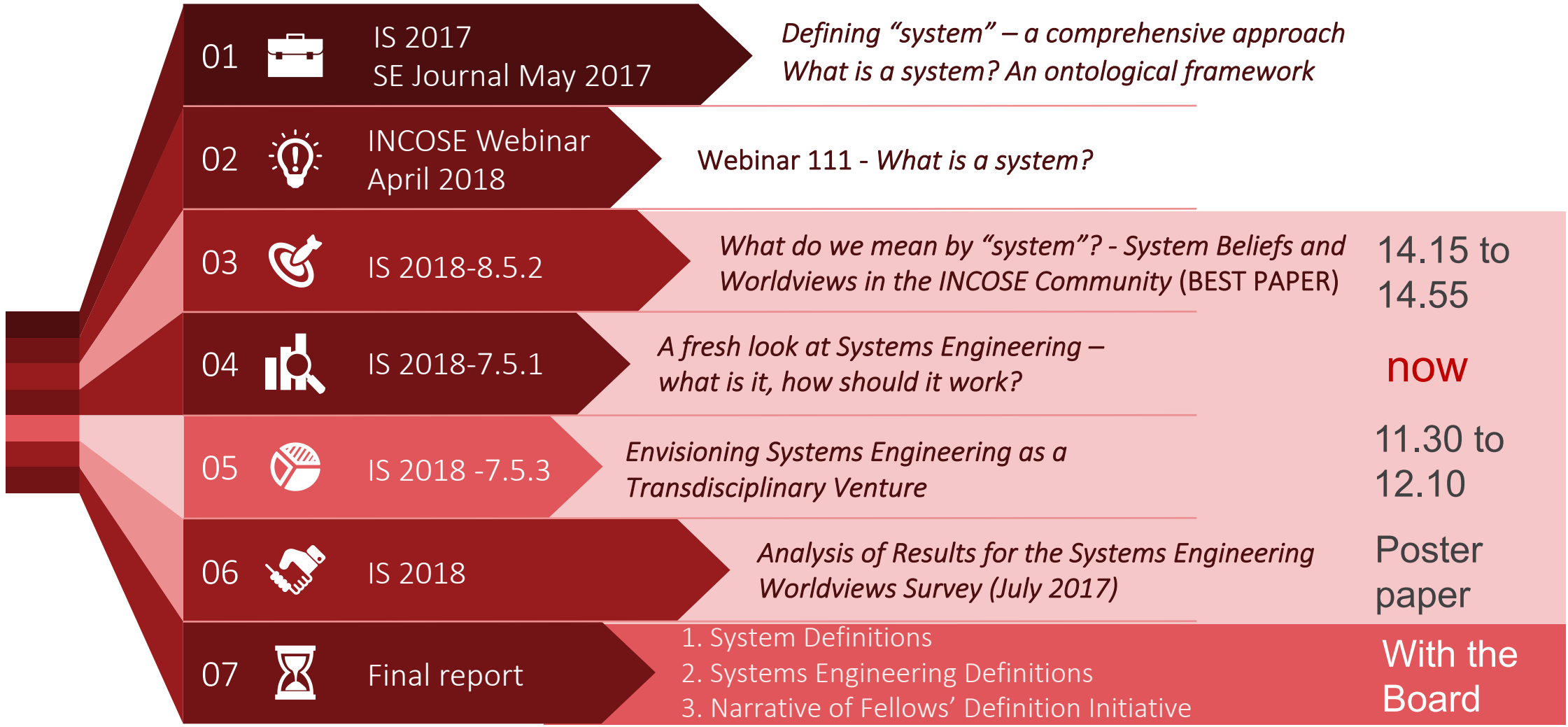
Purpose - Fellows Initiative

- *A Task Team of INCOSE Fellows to write a white paper that contains a definition of systems engineering that reflects the consensus for INCOSE Fellows.*
- *The purpose of this white paper is to distill the discussion of the definition of systems engineering so it is constructive and helpful to both systems engineering practitioners, and to those INCOSE is reaching out to educate about the value of systems engineering.*

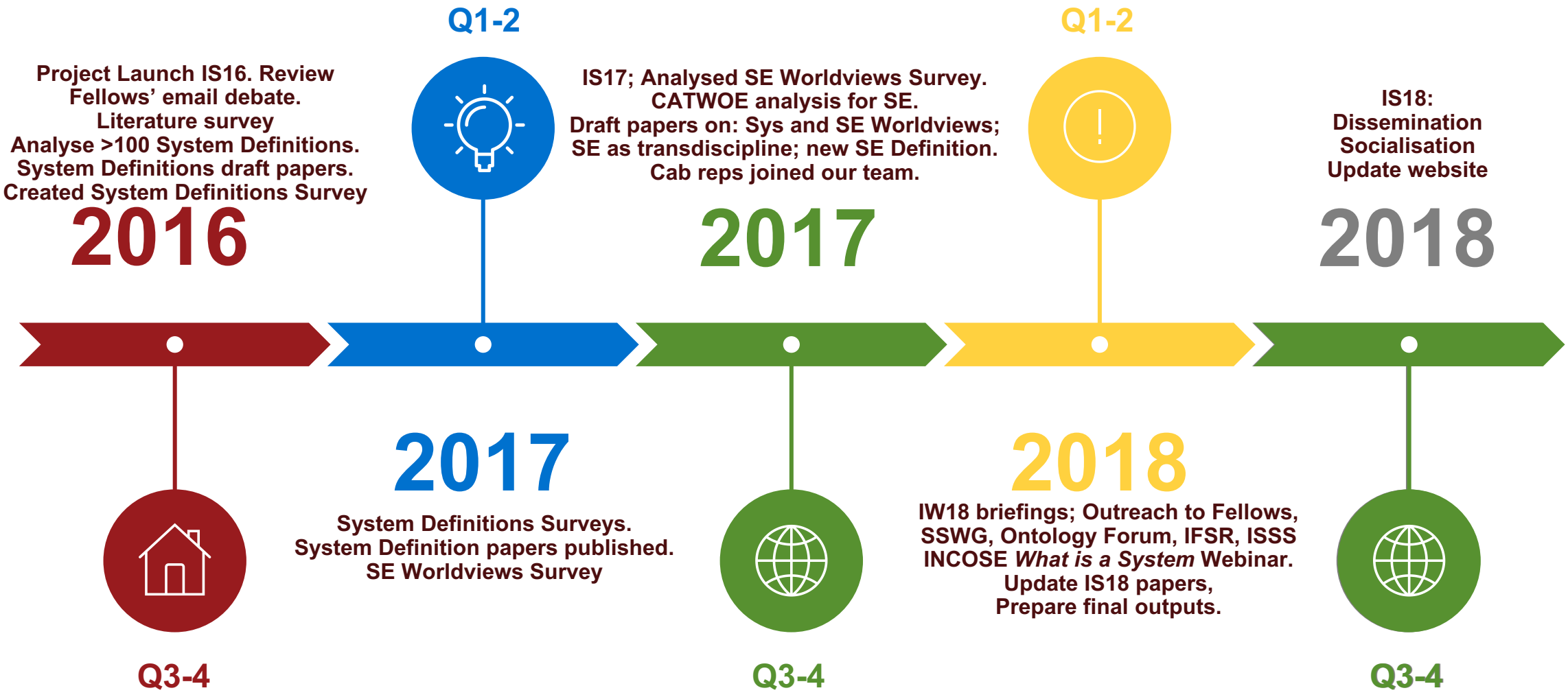
Fellows' Initiative - Task statement (Dorothy McKinney, May 2016)

- This presentation includes updates since submission and linkage to papers 8.5.2, 7.5.3, and poster/reserve paper at IS2018

Where the work is described



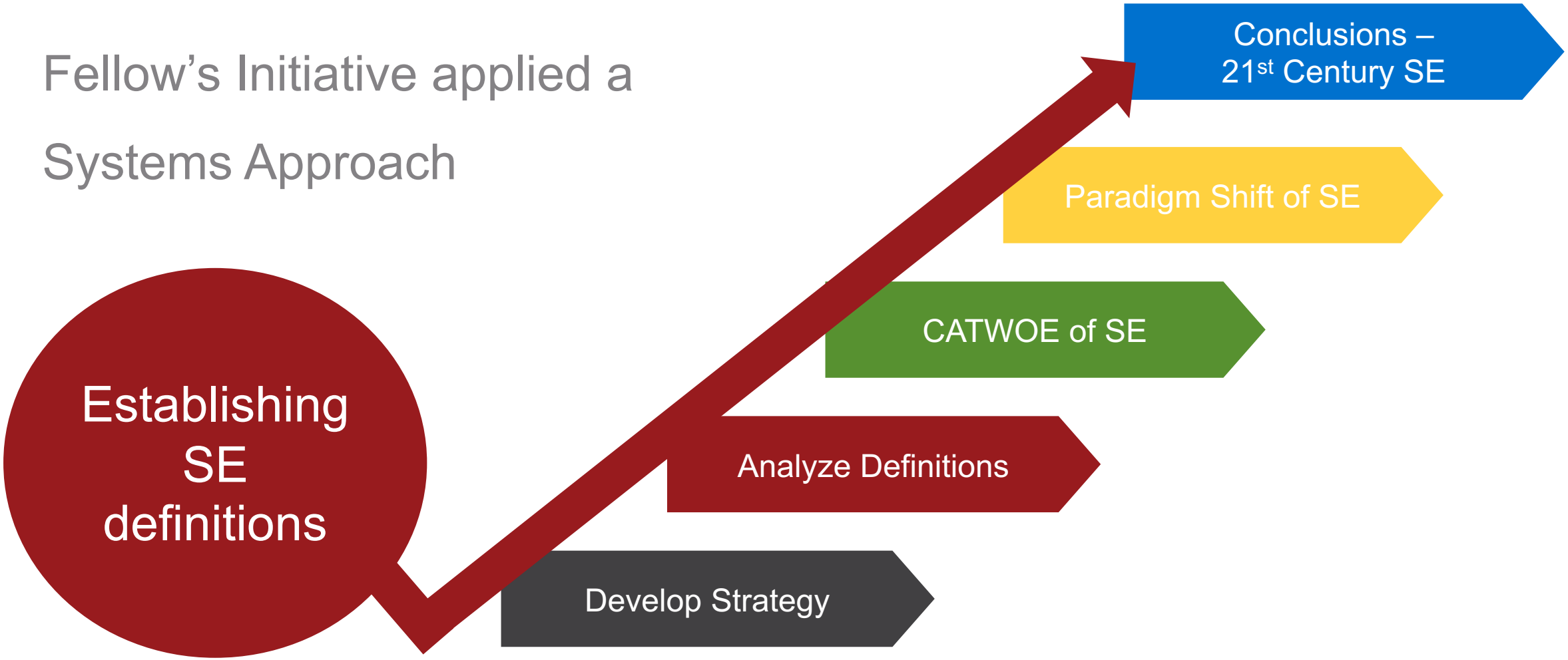
Summary of project



The learning journey

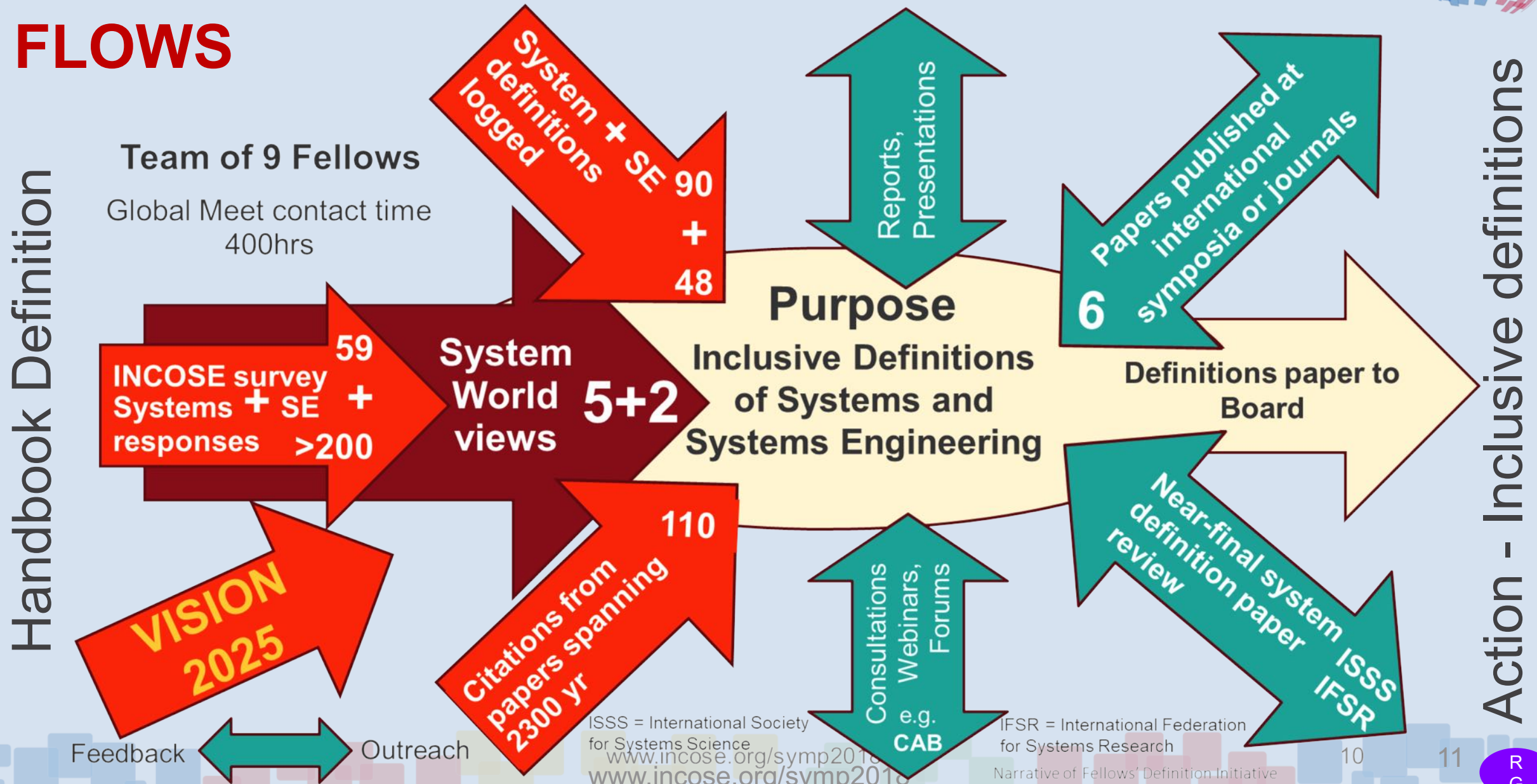
Fellow's Initiative applied a

Systems Approach



Definitions

STUDY INFORMATION FLOWS



ISSS = International Society for Systems Science

IFSR = International Federation for Systems Research

What is a system?

A system is a structured set of parts or elements, which together exhibit behaviour or meaning that the individual parts do not.

- ‘Behaviour’ refers to physical systems
- ‘Meaning’ refers to conceptual system
- Further layers of definition provided in paper 8.5.2 presentation

Current SE Definition

Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems.

It focuses on

- defining customer needs and required functionality early in the development cycle,
- documenting requirements,
- proceeding with design synthesis and system validation while considering the complete problem: Operations, Performance, Test, Manufacturing, Cost & Schedule, Training & Support, Disposal.

Systems Engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation.

Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the users needs.

INCOSE homepage: https://www.incose.org/systems-engineering

Transformation of SE Definition

Present paradigm

robust, dependable, mainly-technological, **"deterministic systems"**

implicitly, a **command and control** view of how SE works

Future paradigm

resilient, adaptive, **"evolutionary"** systems and systems-of-systems

- encompassing products, services and enterprises
- integrating technological, social and environmental elements

explicitly, a collaborative view of how SE works

Proposed SE Definition (changes highlighted)

Systems Engineering is ~~an interdisciplinary~~ a transdisciplinary approach and means, based on systems principles and concepts, and applying scientific, technological and management methods, to enable ~~the realization of~~ successful realization, use and retirement of **engineered systems**.

It focuses on

- establishing and aligning stakeholders' goals, purpose and success criteria, and defining actual or anticipated customer needs and required functionality early in the development cycle,
- establishing an appropriate lifecycle model, process approach and governance structures, considering the levels of complexity, uncertainty and change
- documenting and modelling requirements and solution architecture for each phase of the endeavour
- proceeding with design synthesis and system validation while considering the complete problem and all necessary enabling systems and services.

Systems Engineering provides facilitation, guidance and leadership to integrate all the disciplines and specialty groups into a team effort forming an appropriately structured development process that proceeds from concept to production to operation, evolution and eventual disposal.

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Proposed SE Definition

Systems Engineering is a transdisciplinary approach and means, based on systems principles and concepts, and applying scientific, technological and management methods, to enable the successful realization, use and retirement of engineered systems.

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Methodology

Methods used to establishing new SE definition

1. Prior context and assumptions — Using Checkland's CATWOE
2. Paradigm Shift of SE — To Vision 2025
3. Describe SE in new Context — **Using concept model**
4. Redefine SE — **Using process model in 3 domains**

Applying systems approach ourselves

Identifying context and assumptions for modeling used

CATWOE of Systems Engineering

CATWOE – **C**ustomer, **A**ctors, **T**ransformation,
Weltanschauung, **O**wners, **E**nvironment
Peter Checkland Soft Systems Methodology

CATWOE for SE (1/2)

- **Customer:** Problem owners, stakeholders relevant to *SE Context System*, and society
- **Actors:** SE practitioners in collaboration with relevant practitioners with domain, discipline expertise, and required cognitive/behavioral skills
- **Transformation:** from an unstructured problem/ opportunity to a comprehensive approach to enabling realization of a whole system solution
  - Structured definition of problem/opportunity; stakeholder interests, purpose(s), and success criteria; an effective and fit-for-purpose system solution; an effective and efficient process for developing, deploying, supporting, operating and retiring the system, and for assessing its effectiveness
  - Ongoing and regularly updated estimate of system effectiveness/fitness for purpose and the potential for, and risk of, adverse unintended consequences for stakeholders/ wider society/ environment
  - Enabling activities to ensure the success of both the system and the context system

CATWOE used to create the concept model

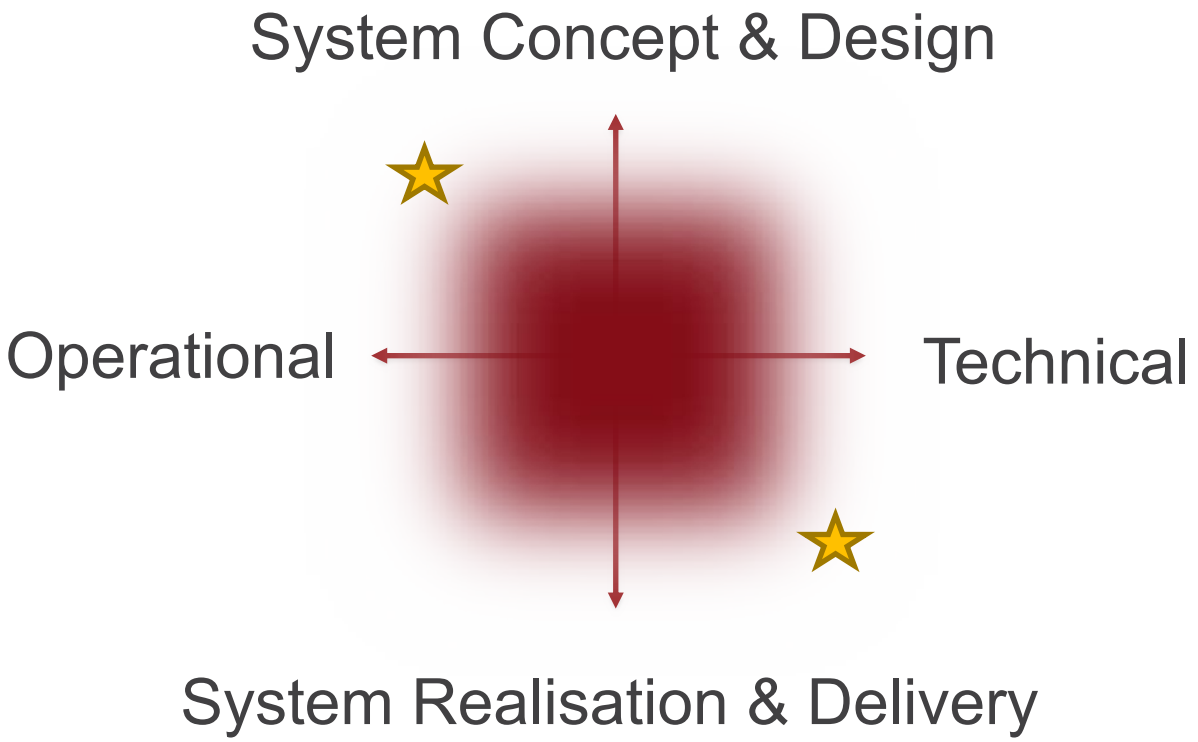
CATWOE for SE (2/2)

- **Weltanschauung (worldview):**
  - Holistic and interdisciplinary; key skills are systems analysis/ thinking and depends on people with wide range of skills working together
  - Defining characteristic of SE is the manipulation of relationships, interfaces and interactions between the parts of the system *and the "Context System for SE"*
  - Overall goal is to enable success of both the system and the "*Context System for SE*" while avoiding deleterious/ harmful unintended consequences
  - Involves SE practitioners with both systemic and systematic skills
- **Owners:** sponsors/problem owner
- **Environment:** SE operates in "*Context System for SE*", a loosely coupled network of organizations comprising all entities involved in creating, operating, supporting, evolving, and retiring the system of interest throughout its lifecycle.
  - SE may operate in a centralized or distributed fashion
  - Opportunity to move from inter-disciplinary to trans-disciplinary (discussed in paper 7.5.3)

CATWOE used to create the concept model

Worldviews on Systems Engineering

- > 200 surveyed IS2018 poster paper
- 48 definitions analysed
- Distribution reflects respondents/definition focus
- Not inconsistent with *systems* worldview map



denotes extreme positions in original definitions

To INCOSE Vision 2025

Paradigm Shift of SE

From	Widened To
"Ballistic" SE – System trajectory set by initial conditions established at start of lifecycle	"Goal-oriented" SE – System trajectory monitored and adjusted to achieve and maintain fitness for purpose throughout the system lifecycle
Complexity feared and minimized	Complexity understood and managed
"Deterministic" systems	"Evolutionary" systems
SE defined as technical and management process activities associated with (mainly technological) system development and whole-lifecycle support to operations	SE defined as a collaboration between people with a variety of competencies needed for whole-system whole-lifecycle success, including ○ systemic and systematic "SE" knowledge and leadership ○ domain and discipline knowledge (societal and environmental as well as technical) relevant to the problem space and solution options ○ cognitive, behavioral and psychological skills applied both to SE in its business context, and to the system of interest in its operational context
SE defined rather in a vacuum – vague about the context in which it operates	SE defined as a "human activity system" operating within the "Context System for SE" – specific about the context in which it operates through the whole system lifecycle

Focus of SE “was”

interdisciplinary

dependable, robust, pseudo-deterministic, mainly technological systems

requirements and operational concepts can be established early in the lifecycle and are not expected to change (much) through life

Focus of SE “is” opened out to

transdisciplinary

resilient, adaptive whole-system solutions - systems and SoS - that may be in a state of continual evolution, at least in their operational environment, and probably the solution system as well

systems of interest may be autonomous, possibly involving Artificial Intelligence, probably involving environmental aspects, and certainly involving social aspects as well as engineering and technology.

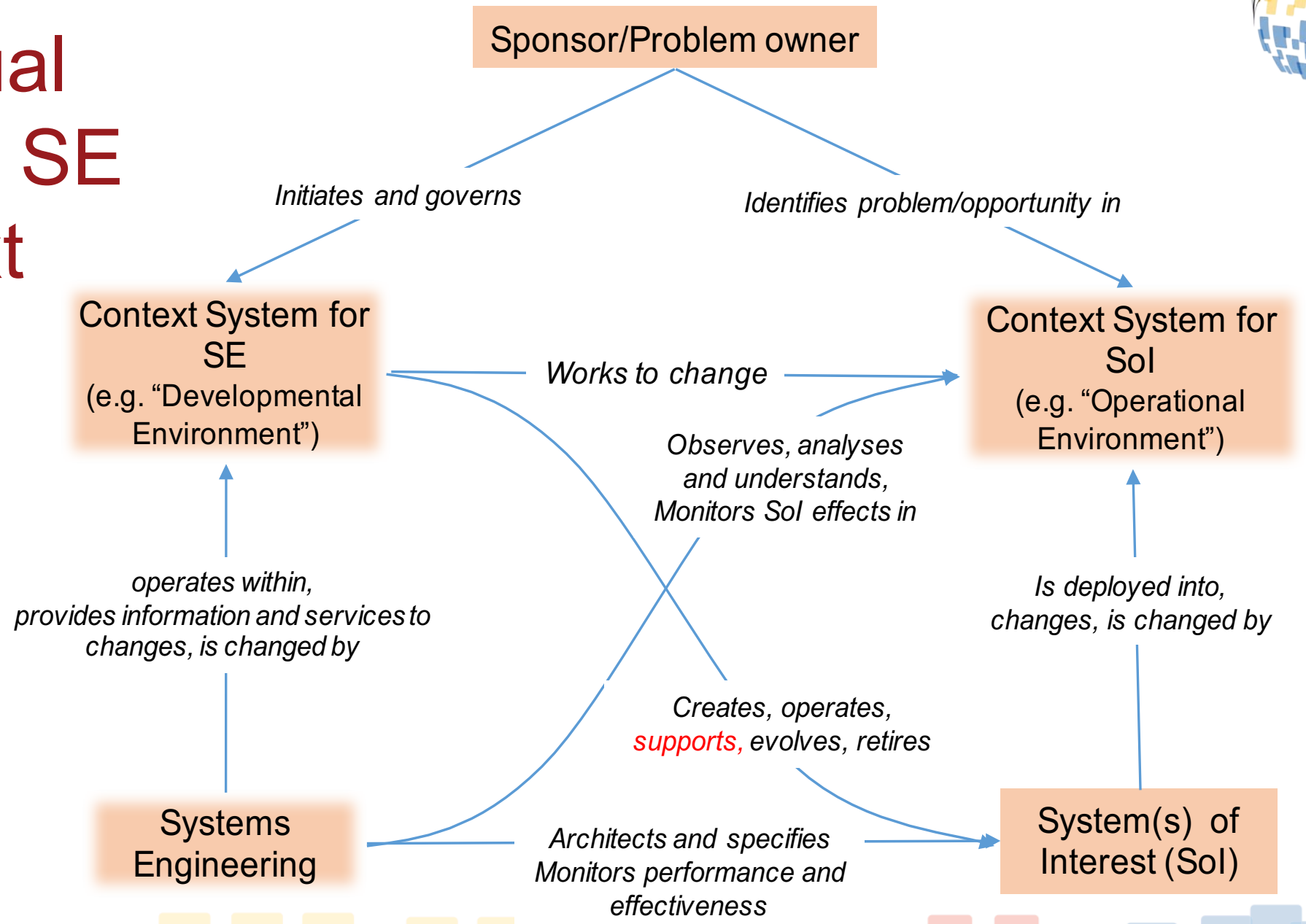
to address societal grand challenges related to the Sustainable Development Goals (SDGs)

Such systems will still need dependable robust technological building blocks (which is why we say the focus “opens out” rather than “shifts”).

Using concept model to show

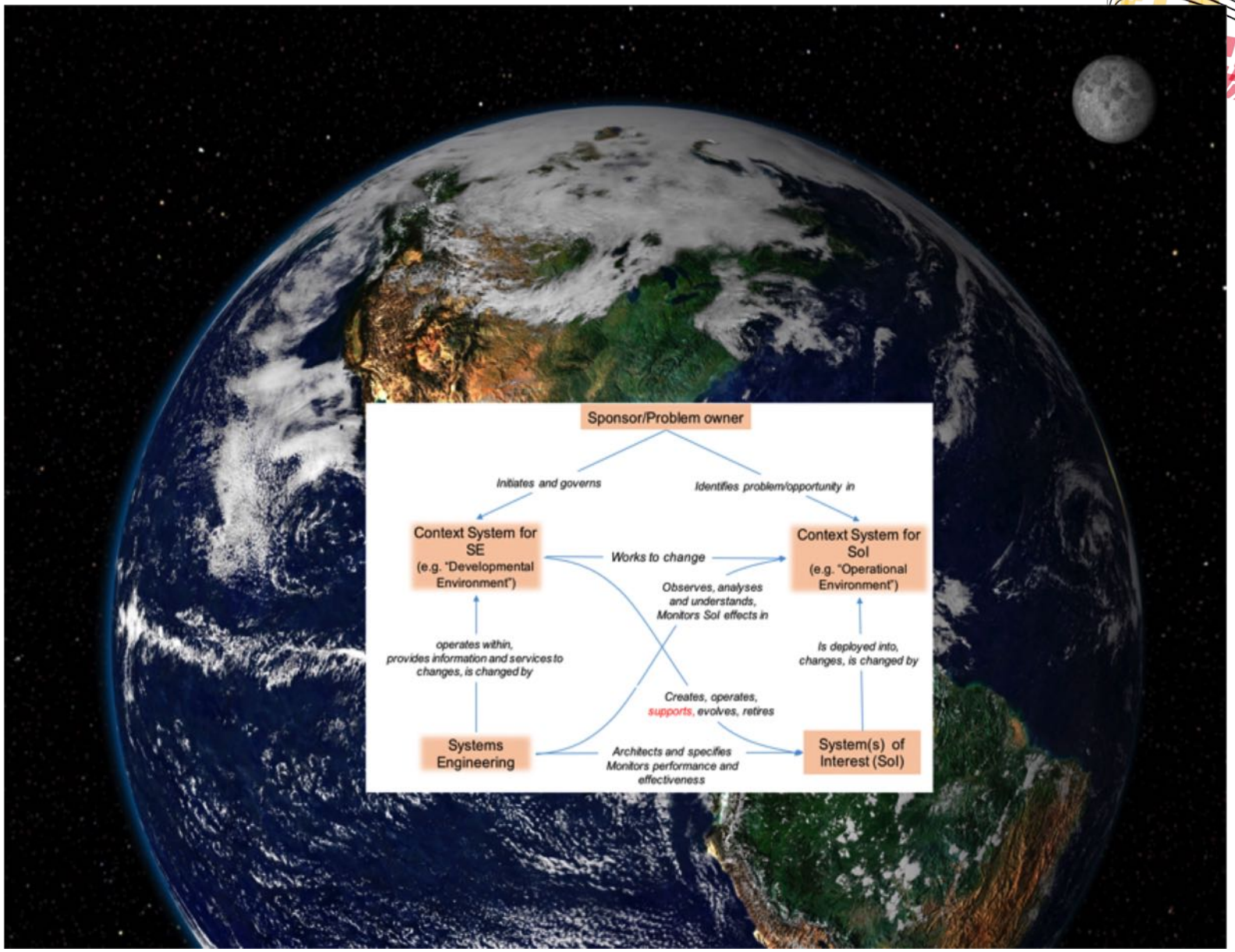
SE in new context

Conceptual Model for SE in Context

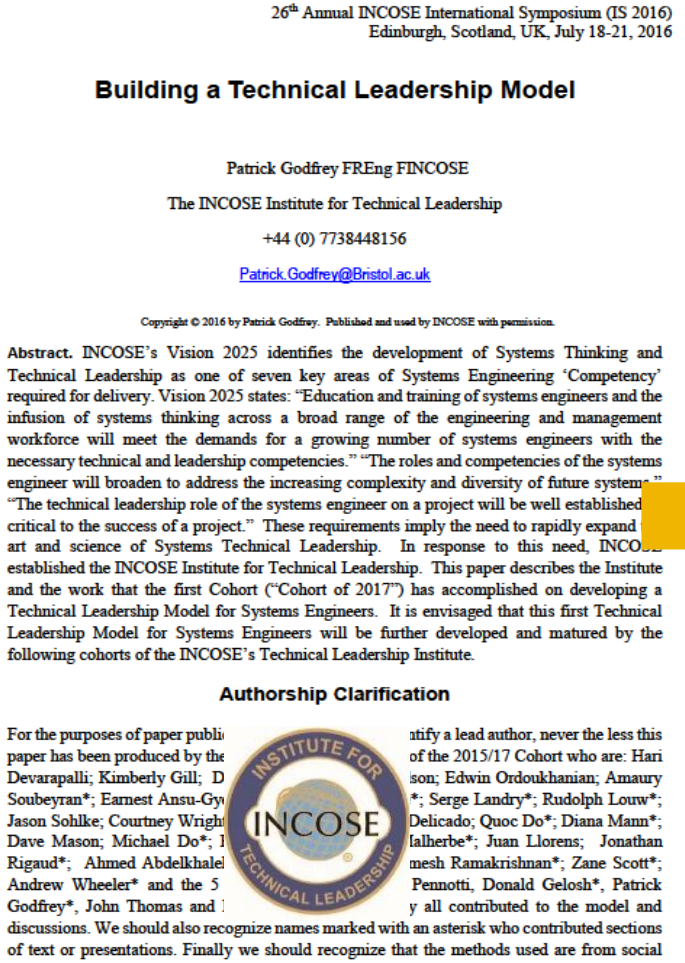


SE in Context is a Holon

SE is both a whole and a part



Characteristics and Interfaces of SE



26th Annual INCOSE International Symposium (IS 2016)
Edinburgh, Scotland, UK, July 18-21, 2016

Building a Technical Leadership Model

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Abstract. INCOSE's Vision 2025 identifies the development of Systems Thinking and Technical Leadership as one of seven key areas of Systems Engineering 'Competency' required for delivery. Vision 2025 states: "Education and training of systems engineers and the infusion of systems thinking across a broad range of the engineering and management workforce will meet the demands for a growing number of systems engineers with the necessary technical and leadership competencies." "The roles and competencies of the systems engineer will broaden to address the increasing complexity and diversity of future systems." "The technical leadership role of the systems engineer on a project will be well established and critical to the success of a project." These requirements imply the need to rapidly expand the art and science of Systems Technical Leadership. In response to this need, INCOSE established the INCOSE Institute for Technical Leadership. This paper describes the Institute and the work that the first Cohort ("Cohort of 2017") has accomplished on developing a Technical Leadership Model for Systems Engineers. It is envisaged that this first Technical Leadership Model for Systems Engineers will be further developed and matured by the following cohorts of the INCOSE's Technical Leadership Institute.

Authorship Clarification

For the purposes of paper publi…tify a lead author, never the less this paper has been produced by the …of the 2015/17 Cohort who are: Hari Devarapalli; Kimberly Gill; D…son; Edwin Ordoukhanian; Amaury Soubeyran*; Earnest Ansu-Gy…*; Serge Landry*; Rudolph Louw*; Jason Sohlke; Courtney Wright…Delicado; Quoc Do*; Diana Mann*; Dave Mason; Michael Do*; I…lalherbe*; Juan Llorens; Jonathan Rigaud*; Ahmed Abdelkhalel…mesh Ramakrishnan*; Zane Scott*; Andrew Wheeler* and the 5…Pennotti, Donald Gelosh*, Patrick Godfrey*, John Thomas and I…y all contributed to the model and discussions. We should also recognize names marked with an asterisk who contributed sections of text or presentations. Finally we should recognize that the methods used are from social

Systems Engineering

- Holds the Vision
- Thinks Strategically
- Fosters Collaboration
- Communicates Effectively
- Enables others to be successful
- Demonstrates Emotional Intelligence

Leadership

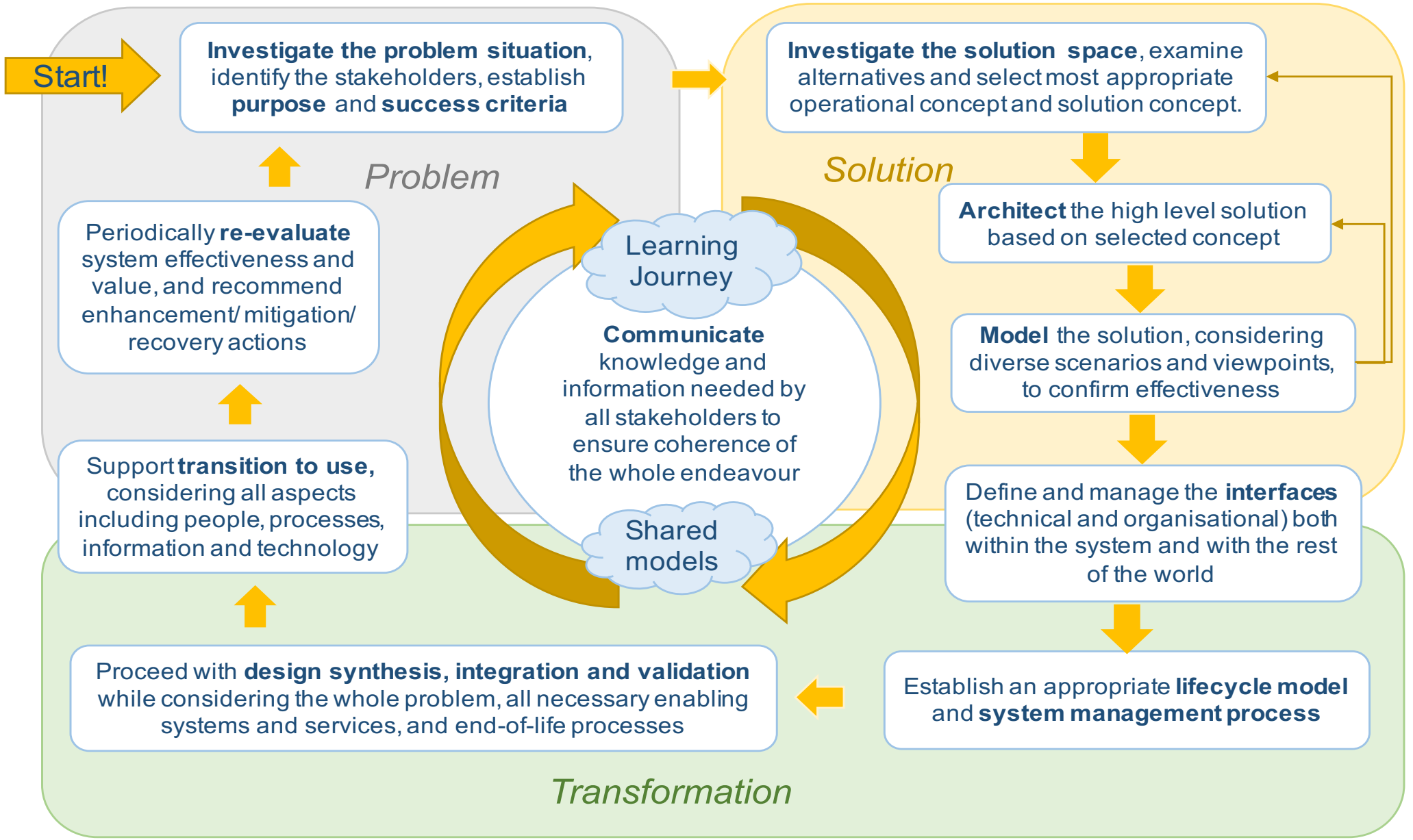
Services offered by SE

- Problem framing
- Clarification of stakeholders purpose and success criteria
- Solution options
- A Process Framework
- An Information Framework
- A Solution Framework
- Evidence of system's predicted and actual performance, effectiveness and fitness for purpose/ unintended consequences
- Evidenced change proposals
- Co-ordination and Leadership

Using a process model to

Summarize the change

Cyclical Process Model & Three Domains



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Proposed Definition (

See paper 7.5.3

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Emphasising that we are inclusive

Reflecting sustainability in Vision 2025

Emphasising the front end and long-term

Solutions that meet the needs of more than users, other stakeholders, intended purpose and no adverse unintended consequences

Modelling and harmonization of models is critical to Modern SE

The role of the SE as [illegible]eader is critical

Long-term whole system solution

Why we are here! Vision 2025

- [illegible]lders' goals, purpose and su[illegible]ed
- establishing an appropriate lifecycle m[illegible]ctures, considering the levels of complexity, uncertainty and change
- documenting and modelling requirements and solution architec[illegible] that are required
- proceeding with des[illegible] synthesis and[illegible]to effort

enabling systems and[illegible]ary

S[illegible]
i[illegible]ers the wider
o[illegible]scape of the whole system solution

Systems Engineering cons[illegible]b[illegible] all [illegible]
qu[illegible]nd is fit for the intended purpose in real-w[illegible]

Questions

Backup

Problem

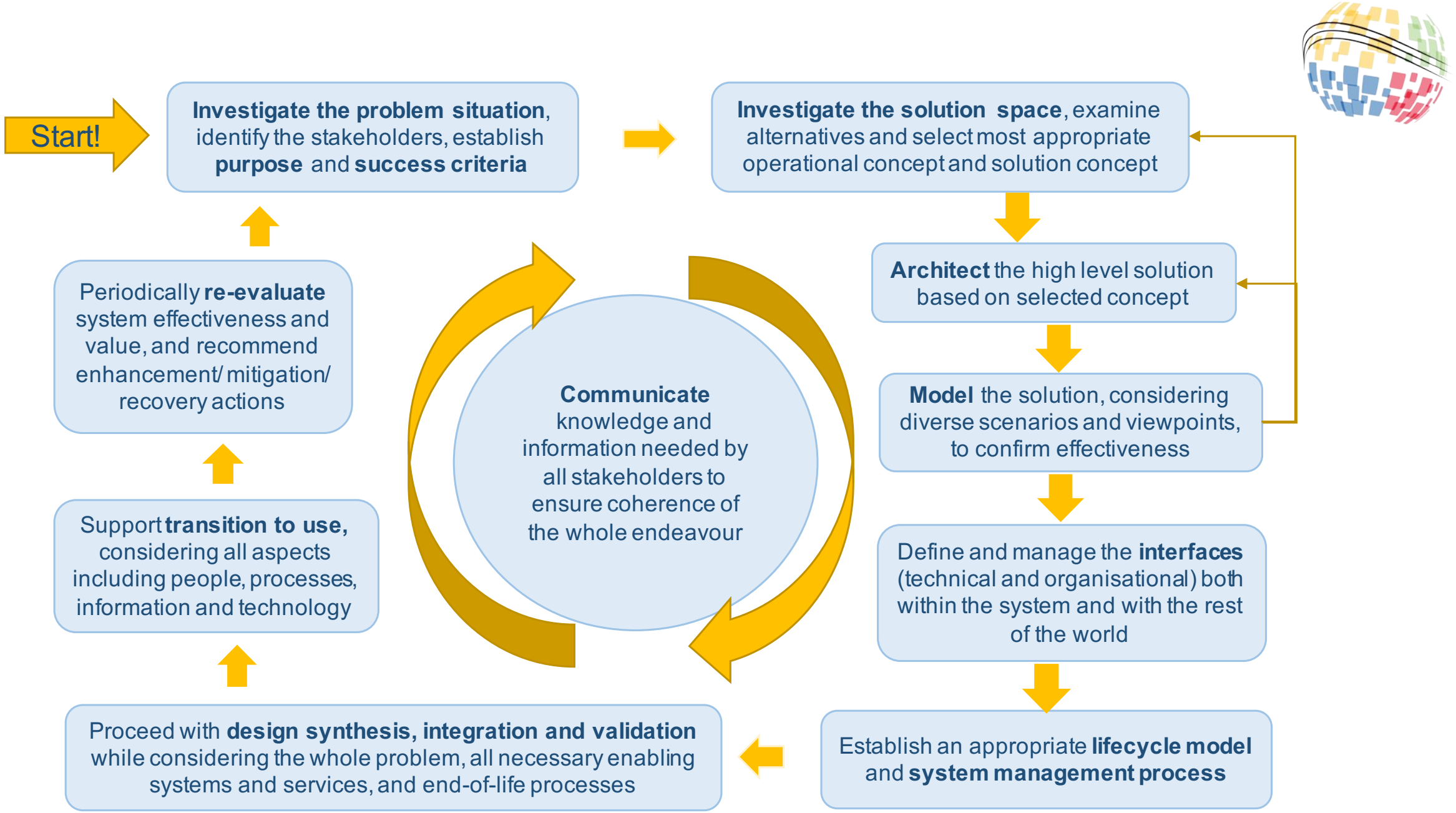
- View the problem as a system.
- Understand how the interdependencies between the elements in the problem space create the "problem symptoms", and how the "intervention system" might alleviate the problem symptoms.
- Understand stakeholder interactions and interdependencies, and establish overall agreed purpose and success criteria.
- Anticipate and aim to minimise potential adverse or unintended consequences of the intervention system.
- Keep scanning for anomalous behaviour and unintended consequences, and for the weak signals that these are emerging – not all can be anticipated beforehand.

Solution

- Identify potential solution approaches.
- Understand how each solution would be used, in other words the operational concept for solving the problem with this solution.
- Select a suitable approach based on evidence and expert judgement, guided by purpose, and taking into account the levels of risk, uncertainty and change.
- Define the solution, the component parts and their properties, and the enabling products and services needed to design, make, test, deploy, use, assess, support, evolve and eventually retire and dispose of the system.

Transformation

- Assess the situation – given the nature and complexity of the problem and solution, decide what sort of Systems Engineering lifecycle approach is most appropriate and most likely to succeed.
- Realise that different disciplines and organisations have different ways of working, which are efficient in isolation but may be incompatible with each other - this is an example of the systems principle that *the parts need to be adapted to serve the purpose of the whole*.
- Provide leadership, facilitation and management as appropriate to enable the realisation and continuing success of the system.


Start!
Investigate the problem situation, identify the stakeholders, establish purpose and success criteria
Investigate the solution space, examine alternatives and select most appropriate operational concept and solution concept
Architect the high level solution based on selected concept
Model the solution, considering diverse scenarios and viewpoints, to confirm effectiveness
Define and manage the interfaces (technical and organisational) both within the system and with the rest of the world
Establish an appropriate lifecycle model and system management process
Proceed with design synthesis, integration and validation while considering the whole problem, all necessary enabling systems and services, and end-of-life processes
Support transition to use, considering all aspects including people, processes, information and technology
Periodically re-evaluate system effectiveness and value, and recommend enhancement/ mitigation/ recovery actions
Communicate knowledge and information needed by all stakeholders to ensure coherence of the whole endeavour

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Focus of SE is: ○ interdisciplinary ○ to engineer dependable, robust, pseudo-deterministic, mainly technological systems ○ requirements and operational concepts that ○ can be established early in the lifecycle ○ are not expected to change (much) through life	Focus of SE is opened out: ○ transdisciplinary ○ to address resilient, adaptive systems and systems-of-systems that may be in a state of continual evolution (at least their operational environment, and probably the system as well), ○ systems of interest may be autonomous, possibly involving Artificial Intelligence, probably involving environmental aspects, and certainly involving social aspects as well as engineering and technology. ○ to address societal grand challenges related inter alia to the Sustainable Development Goals (SDGs) ○ Such systems will still need dependable robust technological building blocks (which is why we say the focus "opens out" rather than "shifts").

Proposed SE Definition (highlighted)

See paper 7.5.3

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Reflecting sustainability in Vision 2025

It focuses on:

- establishing and aligning stakeholders' goals, purpose and success criteria early in the development cycle, considering needs and required functionality early in the development cycle;
- establishing an appropriate lifecycle model, process approach and governance structures, considering the levels of complexity, uncertainty and change
- requirements and solution architecture for each phase of the endeavour
- and system validation while considering the complete problem and all necessary

Emphasising that we are inclusive

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Elements that are required for success tailored to effort

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Modelling and harmonization of models is critical to Modern SE

This considers the wider landscape of the whole system solution

The role of the SE as leader is critical

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