28th Annual INCOSE international symposium

Washington, DC, USA
July 7 - 12, 2018

Session 8.5.2 – Presented by Patrick Godfrey and James Martin

What do we mean by “system”? – System Beliefs and Worldviews in the INCOSE Community

Analysis and Results for the Systems Engineering Worldviews study

Introduction

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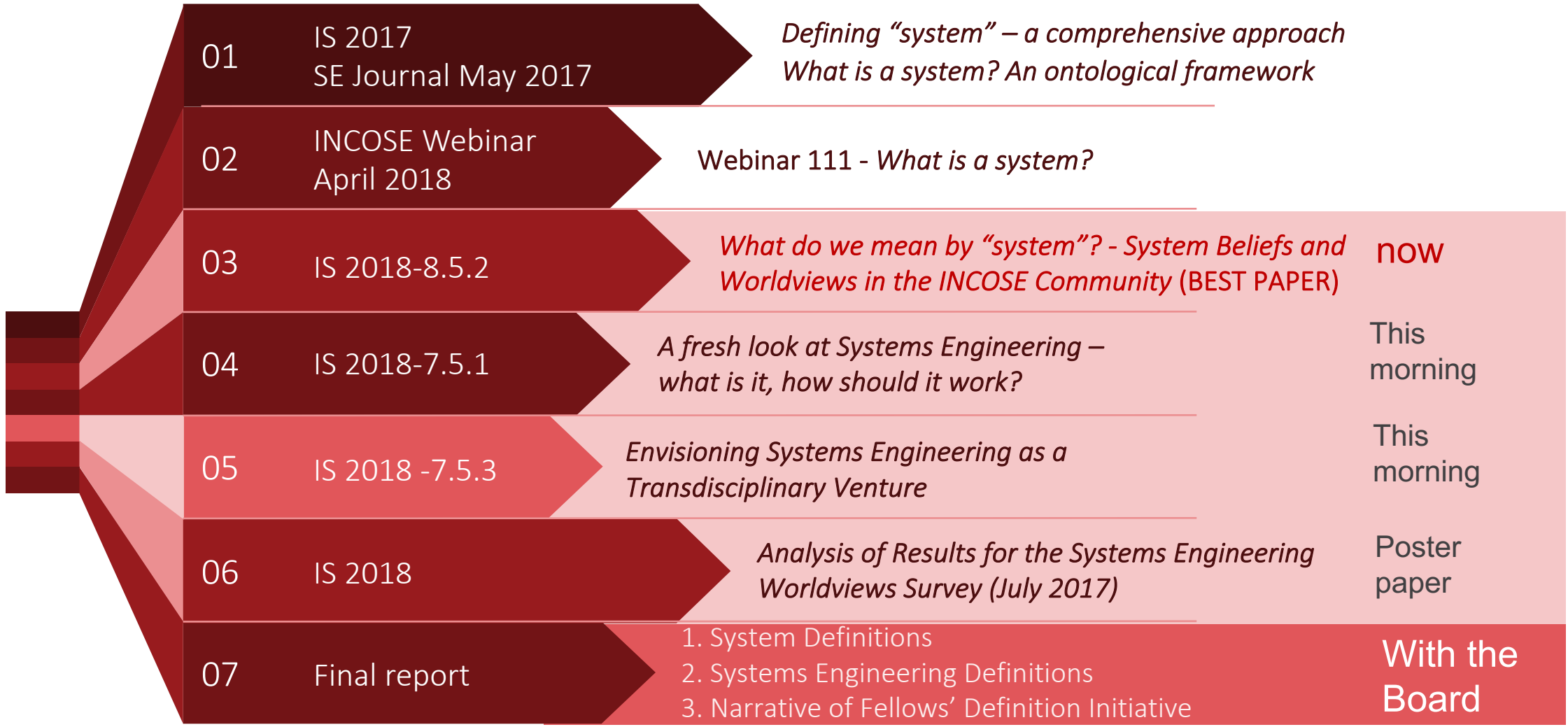
Purpose - Fellows Initiative

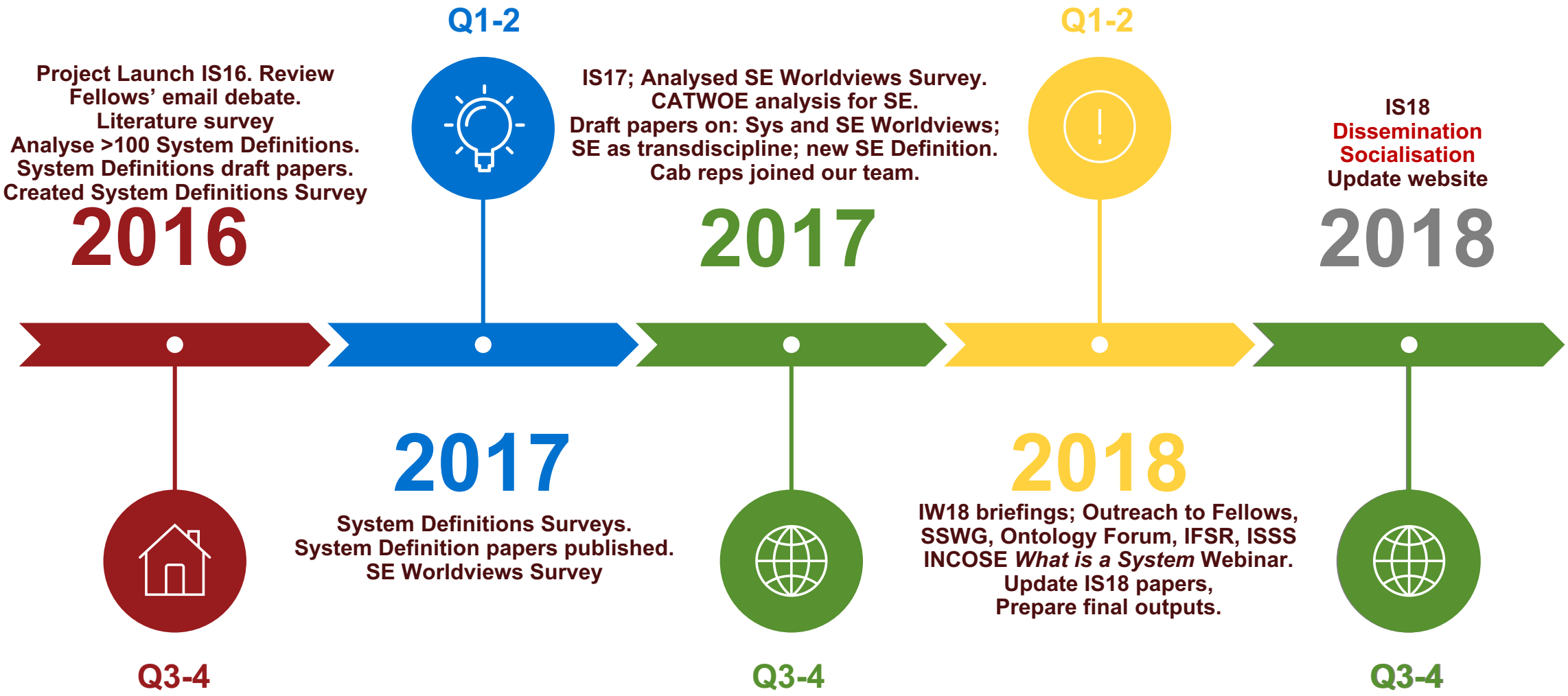
- *A Task Team of INCOSE Fellows to write a white paper that contains a definition of systems engineering that reflects the consensus for INCOSE Fellows.*
- *The purpose of this white paper is to distill the discussion of the definition of systems engineering so it is constructive and helpful to both 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)

Where the work is described



Summary of project



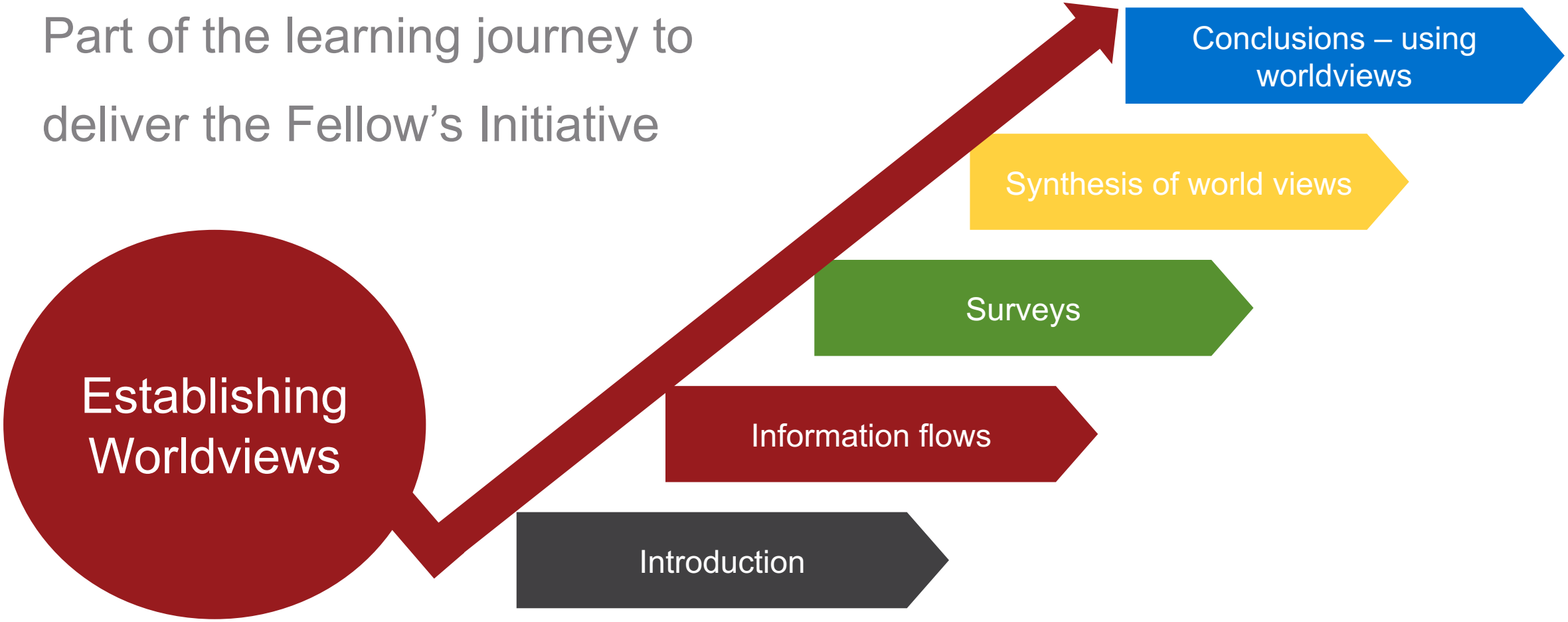
Purpose of this paper

- This paper presents an analysis of the responses from INCOSE surveys and relates these to prior literature. Five distinct worldviews are identified from the survey responses, and two more are identified from subsequent correspondence.

- It also includes the definition we propose for System and Systems Engineering

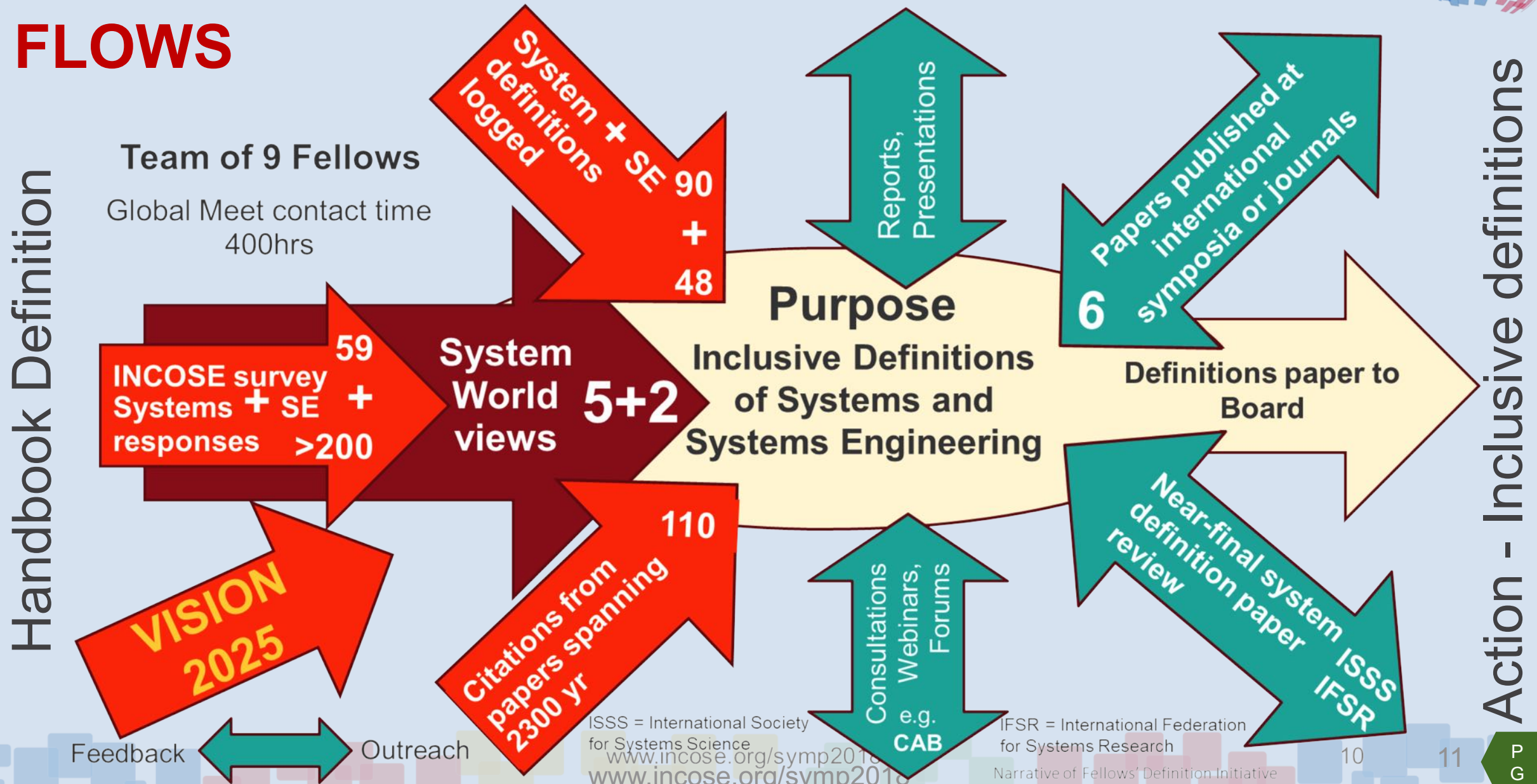
The start of a learning journey

Part of the learning journey to deliver the Fellow's Initiative



Information flows

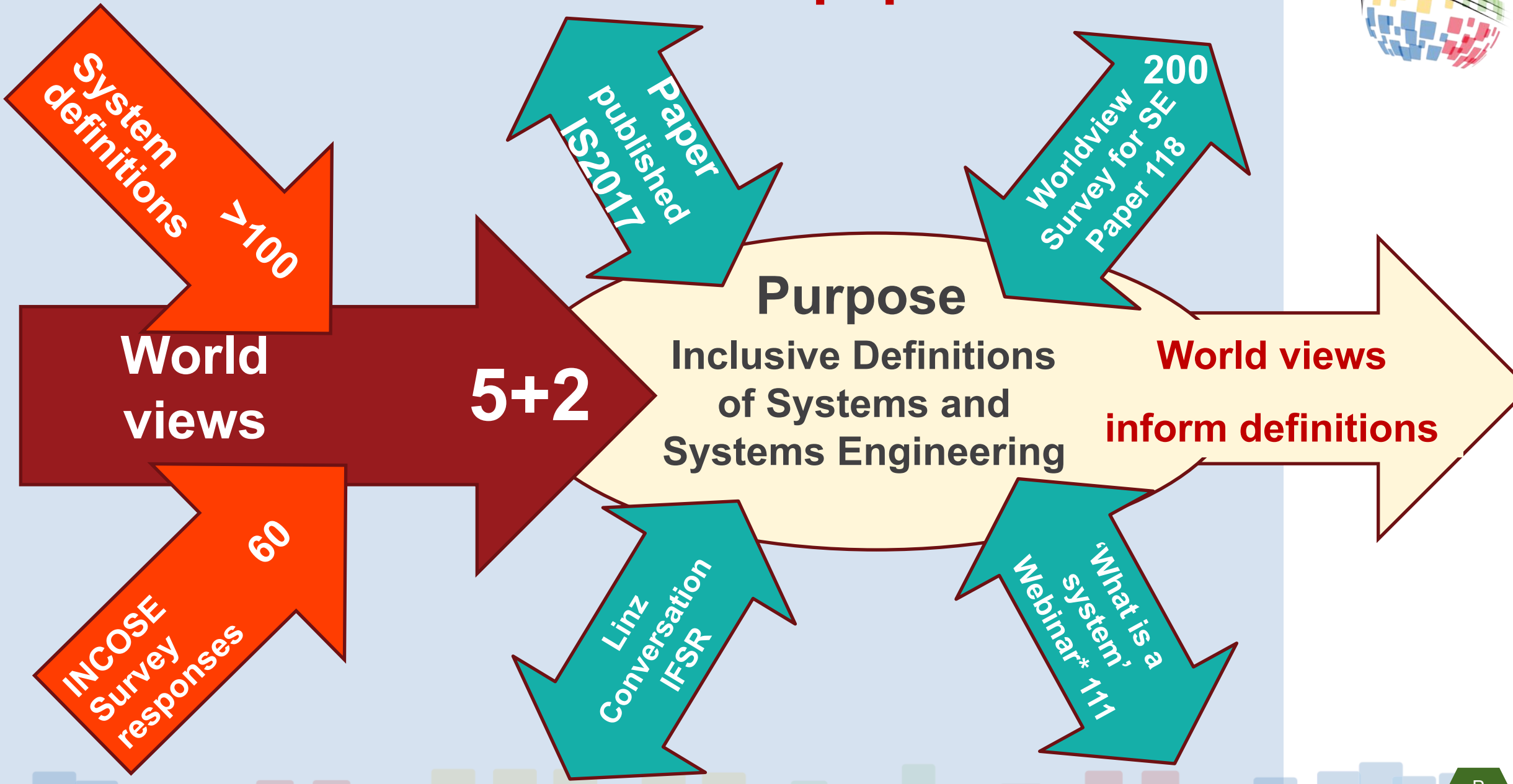
STUDY INFORMATION FLOWS



ISSS = International Society for Systems Science

IFSR = International Federation for Systems Research

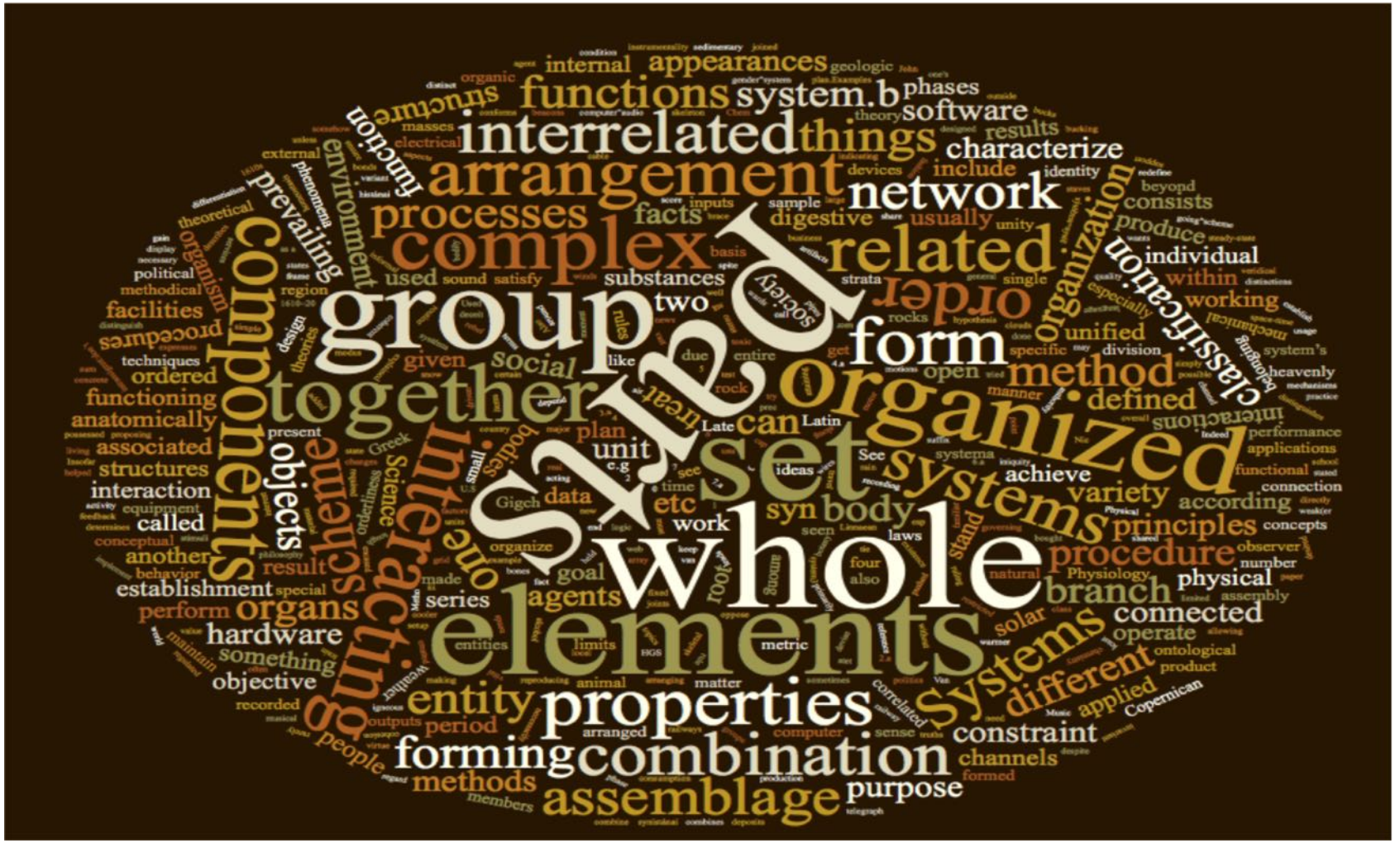
WORLDVIEWS: Focus of this paper



Literature Search & Surveys

Literature Search

- ~100 definitions of “system” were extracted from the literature
- Going back over 2500 years!



Steps we followed

Fellows Email Thread: ~100 emails → revealed disparate views

Literature survey ~100 definition → wide range of concepts

Key Finding: different beliefs about systems

Hypothesis: Failure to agree was due to tacit assumptions not shared → i.e., different worldviews

Surveys to test hypothesis

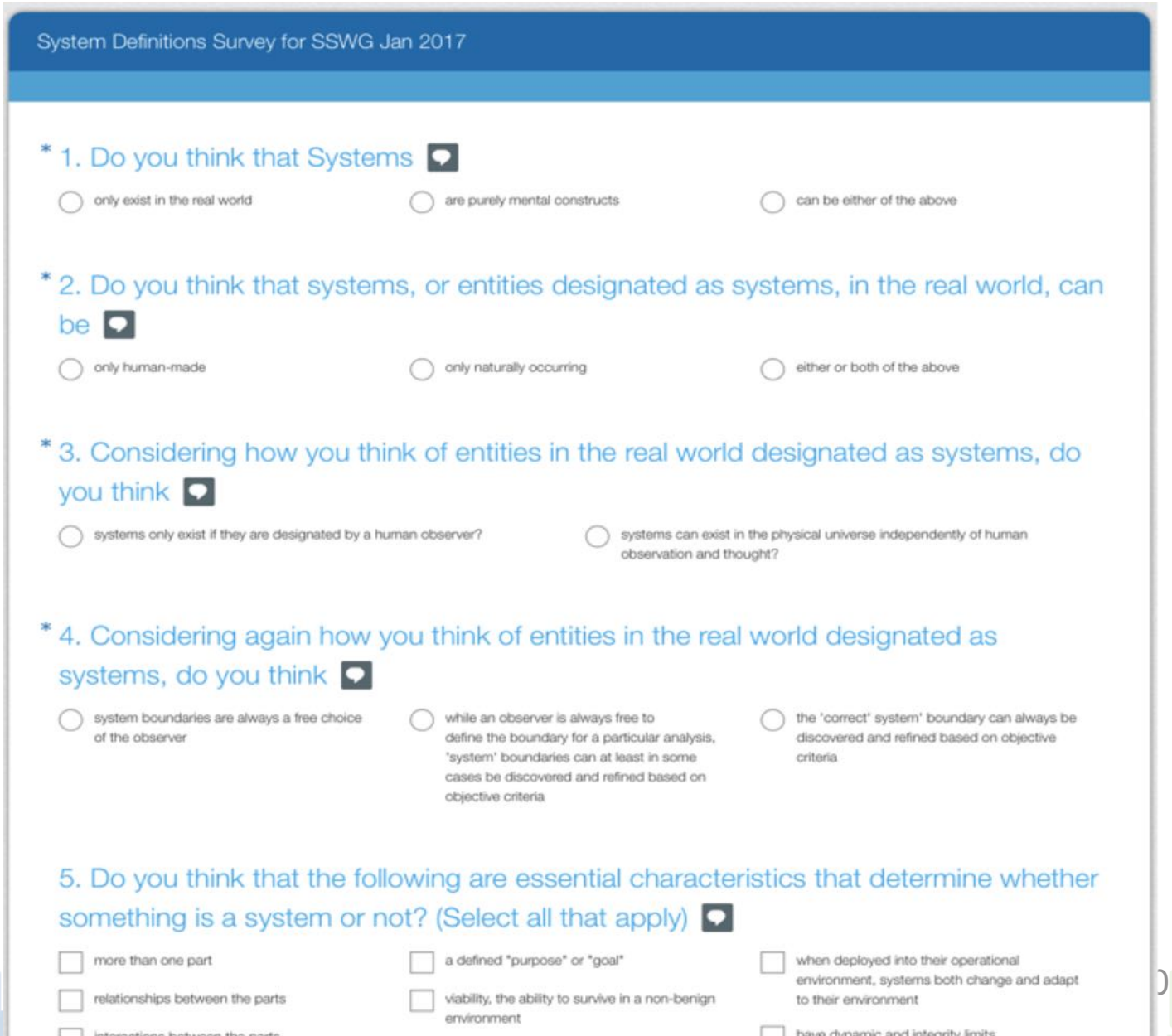
Cluster analysis of responses

5 worldviews "popped out" of the cluster analysis

Systems Philosophy literature – range of worldviews along realist/constructivist spectrum

2 more worldviews were revealed by additional correspondence and discussion

System Definition Survey



System Definitions Survey for SSWG Jan 2017

* 1. Do you think that Systems

- only exist in the real world
- are purely mental constructs
- can be either of the above

* 2. Do you think that systems, or entities designated as systems, in the real world, can be

- only human-made
- only naturally occurring
- either or both of the above

* 3. Considering how you think of entities in the real world designated as systems, do you think

- systems only exist if they are designated by a human observer?
- systems can exist in the physical universe independently of human observation and thought?

* 4. Considering again how you think of entities in the real world designated as systems, do you think

- system boundaries are always a free choice of the observer
- while an observer is always free to define the boundary for a particular analysis, 'system' boundaries can at least in some cases be discovered and refined based on objective criteria
- the 'correct' system' boundary can always be discovered and refined based on objective criteria

5. Do you think that the following are essential characteristics that determine whether something is a system or not? (Select all that apply)

- more than one part
- relationships between the parts
- a defined "purpose" or "goal"
- viability, the ability to survive in a non-benign environment
- when deployed into their operational environment, systems both change and adapt to their environment

- ✓ Designed to elicit different “beliefs” about the nature of systems
- ✓ Five questions were used in the Survey
  - ➢ INCOSE Fellows
  - ➢ Systems Science Working Group

Survey Questions

1) Are they real or a mental construct? Or both?
2) Only manmade or only naturally occurring?
3) Only exist if observer designates as such?
4) System boundaries – intrinsic or observer designated?
5) Essential characteristics of “Systemicity”?

First Question:
Realist or Constructivist?

- Intended to elicit the respondents' position on the basic realist/constructivist spectrum:

- ***Do you think that Systems***
  - ***only exist in the real world?***
  - ***are purely mental constructs***
  - ***can be either of the above***

Second Question:
Human-made or naturally occurring?

- ***Do you think that systems, or entities designated as systems, in the real world, can be:***
  - ***only human made***
  - ***only naturally occurring***
  - ***either or both of the above?***

Sample response summary sheet

	Summary		13	16	8	9	22	25	3	18	7	17	2	4	24	6	19	26	10	14	15	20	1	5	23	12	11	21
Do you think that Systems			Constructivists									"realist consensus"																
exist (only) in the real world?	1																											1
are a mental construct	4		1	1	1	1																						
can be both of the above	21						1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Do you think that systems, or entities designated as systems, in the real world, can be																												
human made	1								1																			
naturally occurring	0																											
either or both of the above	25		1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Considering how you think of entities in the real world described as systems, do you think																												
systems only exist if they are designated by a human observer?	6		1	1	1	1	1	1																				
systems can exist in the physical universe independent of human observation and thought?	19								1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1
Considering again how you think of entities in the real world described as systems, do you think																												
system boundaries are always a free choice of the observer	5			1	1	1			1	1																		
while an observer is always free to designate the boundary for a particular analysis, 'system' boundaries can at least in some cases be discovered and refined based on objective criteria	20		1				1	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1
the 'correct' system' boundary can always be discovered and refined based on objective criteria	1																										1	
other	0																											
Do you think that the following are essential characteristics of "systems"																												
more than one part or element	24		1	1	1	1	1	1		1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1		
relationships between the parts	24		1	1	1	1	1	1		1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1		1

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Key Findings

❖ Essential Characteristics

- ✓ Nearly 90% considered "emergent properties" as essential characteristics
- ✓ About 25% considered that "a defined purpose or goal" was essential
- ✓ Most respondents took a modest or even a minimalist approach to the essential characteristics that define a system
- ✓ By contrast, a small group (about 12%) consider that all 18 of the "systemic" characteristics listed were essential for something to be considered a system

❖ Real vs Conceptual Systems

- ✓ About 20% are "constructivists" (ie, systems are a human mental construct)
- ✓ About 80% are "moderate realists" (ie, can be either "real" or in the mind)

Synthesis of World Views

Worldviews in context

- Survey results were complex!
  - The team itself had diverse and strongly held views
- Resolved using a systems approach
  - **Purpose** to make sense of the diversity
  - **Method** emergent learning
  - **Improved and validated** by engagement and feedback with the wider community of interest
- **Output** a systemic set of worldviews.

What is a worldview

Referred to in social science

- a particular philosophy of life or conception of the world
- the fundamental cognitive orientation of an individual or society encompassing the whole of the individual's or society's knowledge and point of view.

Information flows used to structure sets of Worldviews

Worldviews used to inform new definitions

5 worldviews from surveys

Worldview 1	**Formal minimalist** - based on mathematics and logic
Worldview 2	**Constructivist** - systems are purely a mental construct
Worldview 3	**Moderate realist** - both mental constructs or physical world
Worldview 4	**Strong & extreme realists** – only physical world
Worldview 5	**Complex, viable and living systems** - only exist in physical world

2 more worldviews from subsequent correspondence

Worldview 6

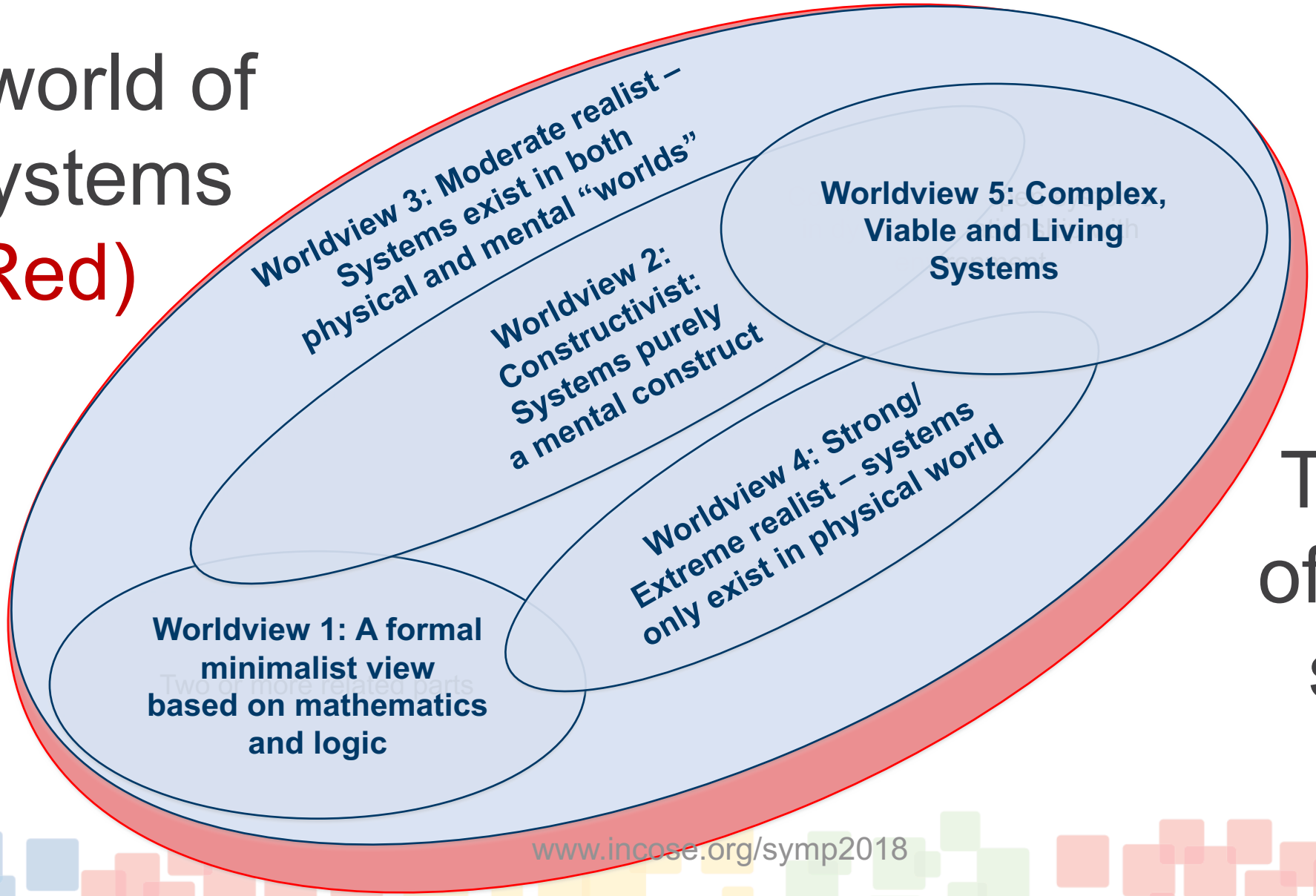
Systems as a Mode of Description - nothing “is” a system, anything can be described as a system

Worldview 7

***System as a process* –** everything changes so can be regarded as a process – applicable to all world views

Mapping 5 worldviews from Surveys

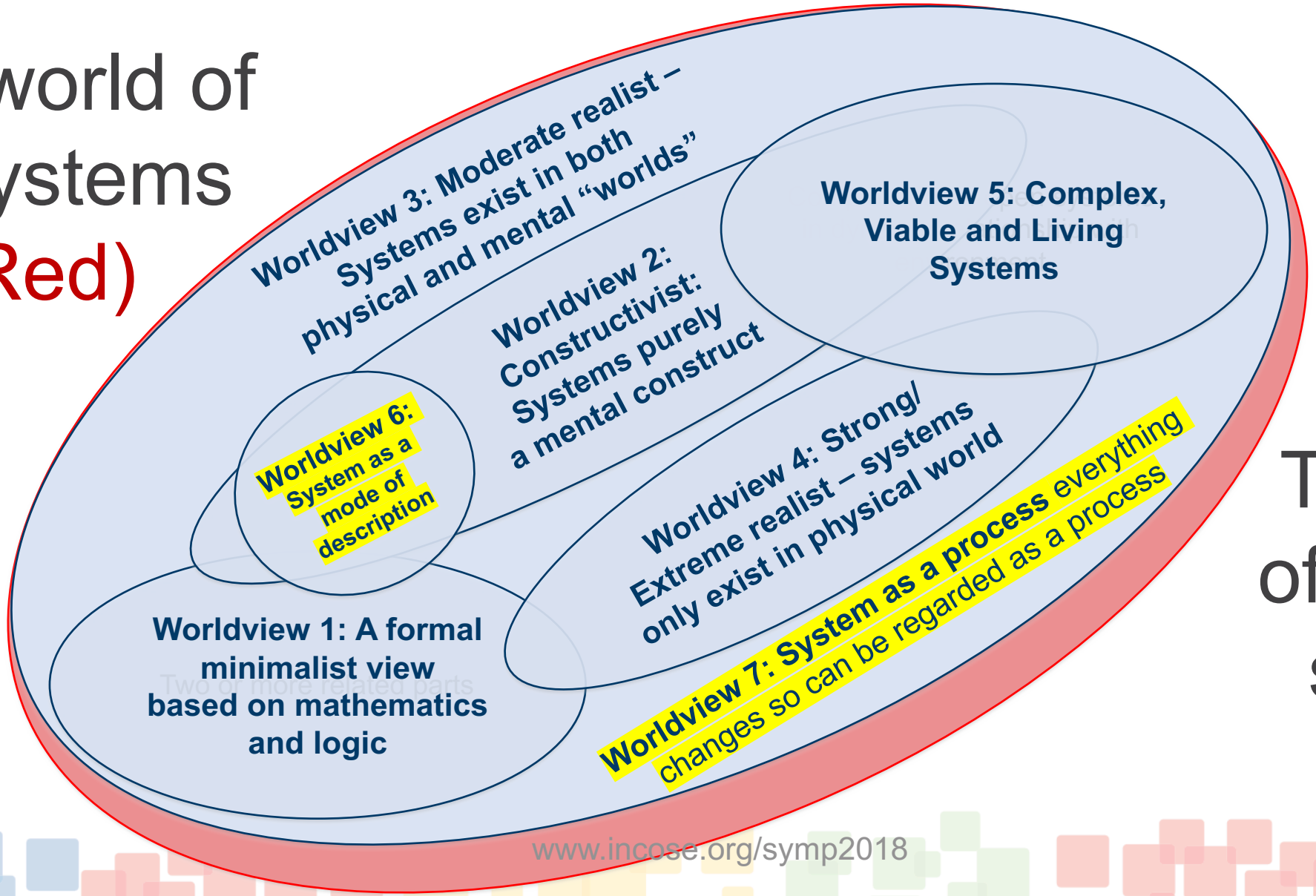
The world of all systems (Red)



The world of INCOSE systems (Blue)

Mapping 5 + 2 worldviews

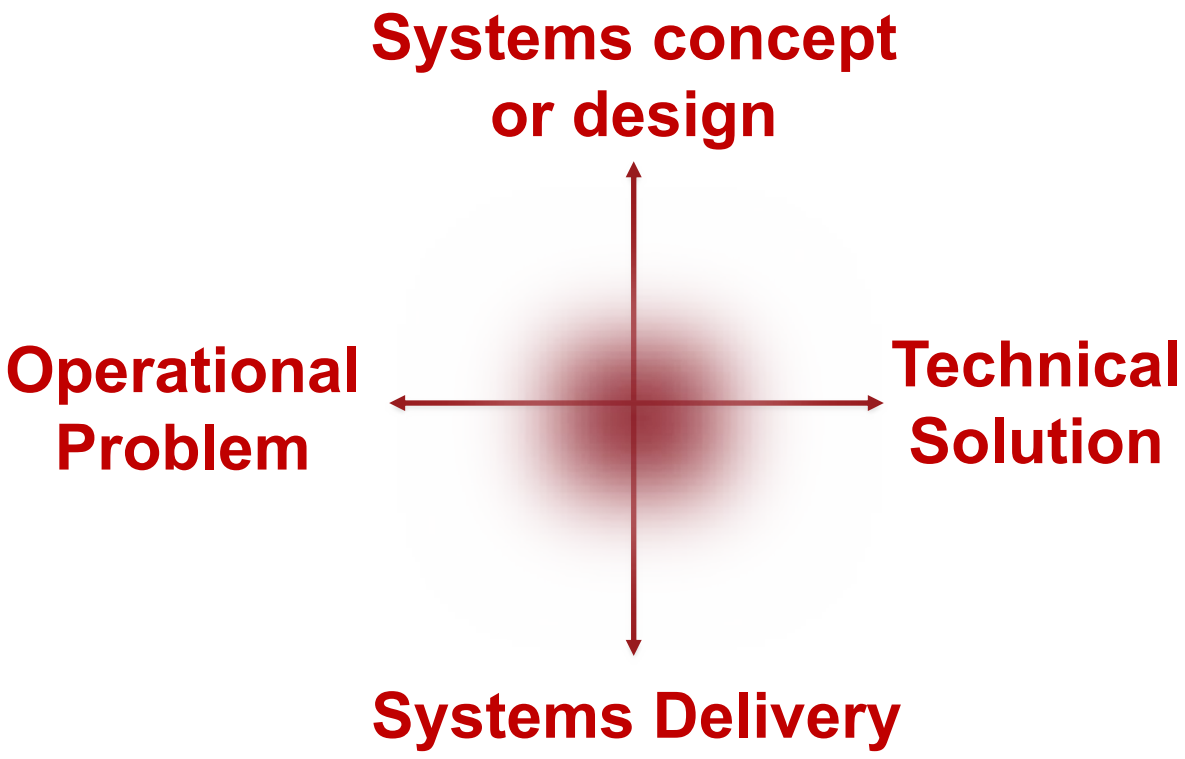
The world of all systems (Red)



The world of INCOSE systems (Blue)

Worldviews on Systems Engineering

- > 200 people surveyed: IS 2018 poster paper
- 48 definitions analysed
- Consistent with *systems* worldview map
- Distribution reflects respondents/definition focus



Summary on systems worldviews

Observations

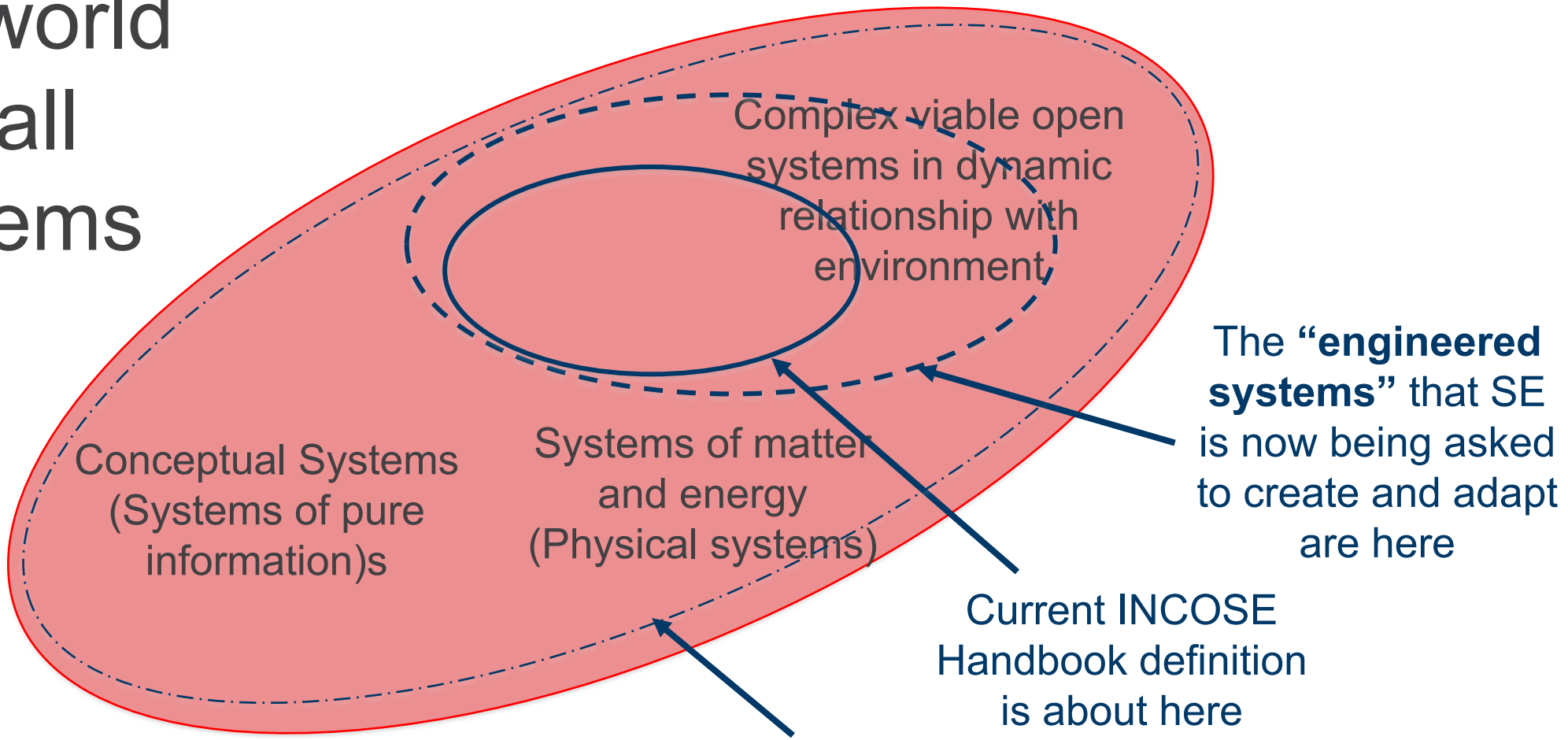
1. No worldview is wrong
2. No worldview is complete
3. The set of worldviews defines a landscape
4. Worldviews overlap - don't 'fit together'
5. Worldview-centred Definitions don't add up to a coherent whole

Implications

1. General definition must encompass all worldviews
2. Subordinate definitions don't map directly to worldviews (because of 4&5 above)

Why we need a new definition of systems

The world of all systems



Conclusion - using world views

Summary and conclusions

- Senior and experienced members of the INCOSE community hold at least 7 quite different worldviews about systems
- Dialogue with Systems Scientists elicited an 8th potentially unifying Worldview.
- To achieve Vision 2025 the Worldviews need to be:
  - Understood in context with other prior publications and further engagement
  - Used to widen our view of systems
  - Adopted as a transdisciplinary integration challenge
  - Recognised that knowledge generation is a never ending process
- This work informs recommendations to INCOSE for an updated set of definitions for “system” and “systems engineering”.

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 are appropriate to different world views

New definitions covering all worldviews

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

- A physical system
- A conceptual system
  - A closed system
  - An open system
  - A viable system
  - A complex system
  - An anticipatory system
  - A natural system
  - An artificial system
  - A hybrid system

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

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

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  - A hybrid system

A closed system is a system that is completely **isolated from its environment.**

An open system is a system that has **flows** of information, energy, or material **between the system and its environment**.

New definitions covering all worldviews

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A viable system is an open system which, within certain environmental limits, **can: sustain itself** by exchanging material, energy and information with its environment; maintain and repair its internal organisation in the face of disruption; and adapt to a changing environment.

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New definitions covering all worldviews

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A Complex System is a system in which there are **uncertain relationships** between cause and effect: each effect may be due to multiple causes; each cause may contribute to multiple effects; and cause-effect chains are circular and entangled rather than linear and separable.

New definitions covering all worldviews

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  - A hybrid system

An anticipatory system is a physical system that has an internal model of itself and its environment, enabling it **to anticipate future changes** in the environment and **make appropriate adaptations** to be ready for the change predicted by the model

New definitions covering all worldviews

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  - An artificial system
  - A hybrid system

A natural system is a system that occurs in nature by natural evolution without intervention from intentional agents.

An artificial system is a system constructed by intentional agents.

New definitions covering all worldviews

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A hybrid system is a system with both **natural and artificial** elements, **or** a natural system **influenced** (e.g. by selective breeding) **or modified** (e.g. by genetic engineering) **by intentional agents.**

New definitions covering all worldviews

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

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An Engineered System is a system designed or adapted to interact with an anticipated operational environment to achieve an intended purpose while complying with applicable constraints.

P.S. for Systems Engineering Practitioners

Worldview analysis has emerged as a systems engineering tool used to:

- **dissolve** the boundaries between conventional disciplines, and belief systems
  - **organizes** us around
    - purpose
    - physical real world context
  - **usable** at any level
    - from complex to simple
    - from global to personal
- **promote** cooperation, collaboration and integration
- **reduce** prejudice and conflict

An enabler for:
- Transdisciplinary Engineering
- Vision 2025

Questions and Discussion

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Thank You!

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Use any of the following as a basis for any additional charts you want to develop

Back up Slides

New definitions covering all worldviews

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A physical system is a

A Complex System is a system in which there are uncertain relationships between cause and effect: each effect may be due to

A Natural System is a system that occurs in nature by natural evolution without intervention from intentional agents.

8th Worldview from Linz 'co

"We see systems everywhere because they are everywhere".
Systemness is the phenomenon that allows regions of organisation in the material world to persist in a dissipative universe.

Based on fundamental conjectures about syst

1. System is a persistent region of low entropy (= org ation) in physical or conceptual space-time
2. Systemness is a fundamental organising principle of nature.
3. Humans are hardwired to recognise "systems" because it has high survival value
4. The universe is the only known closed physical system.
5. System practice and systems science involve two key aspects:
   - Understanding systems
   - Understanding how we perceive and interact with systems

If we build on these ideas we think we can develop an a proach that respects, integrates and builds upon all of the other identified worldvie

(NB many conceptual systems, including all system models, are models of closed systems!!!)

Based on discussions among Team 2, International Foundation for Systems Research (IFSR) Conversation Linz, April 2018

New definitions covering all worldviews

- A system is a structured set of parts or elements, which together exhibit behaviour or meaning that the individual parts do not.
  - **A physical system** is a structured set of parts or elements, which together **exhibit behaviour** that the individual parts do not.
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  - **A natural system** is a system that occurs in nature by natural evolution without intervention from intentional agents.
  - **An artificial system** is a system constructed by intentional agents.
  - **A hybrid system** is a system with both natural and artificial elements, or a natural system influenced (e.g. by selective breeding) or modified (e.g. by genetic engineering) by intentional agents.

Document “System Definitions”, 1st June 2018