Business Object Reference Ontology

BORO Ontology

C-FORS Summer School in Foundational Ontology
(C-FORS 2025)

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Schedule

Morning Sessions		
	9:00 - 9:05	Session 0 – Introduction
	9:05 - 9:45	Session 1 – Context
	10:00 - 10:45	**Session 2 – BORO Ontology**
	11:00 - 12:00	Session 3 – Analysis Tools
Afternoon Sessions		
	1:15 - 3:30	Session 1 – Practical Examples
	3:30 - 5:00	Session 2 – Examples Discussion / Presentation

Business Object Reference Ontology

NOTE: ~tl;dr convention

- Cannot fit the background details into the presentation, so
  - ~tl;dr == don’t read now: reading matter for **later** review
    - if anyone is interested
      - OTOH you could just ask your favourite LLM ☺

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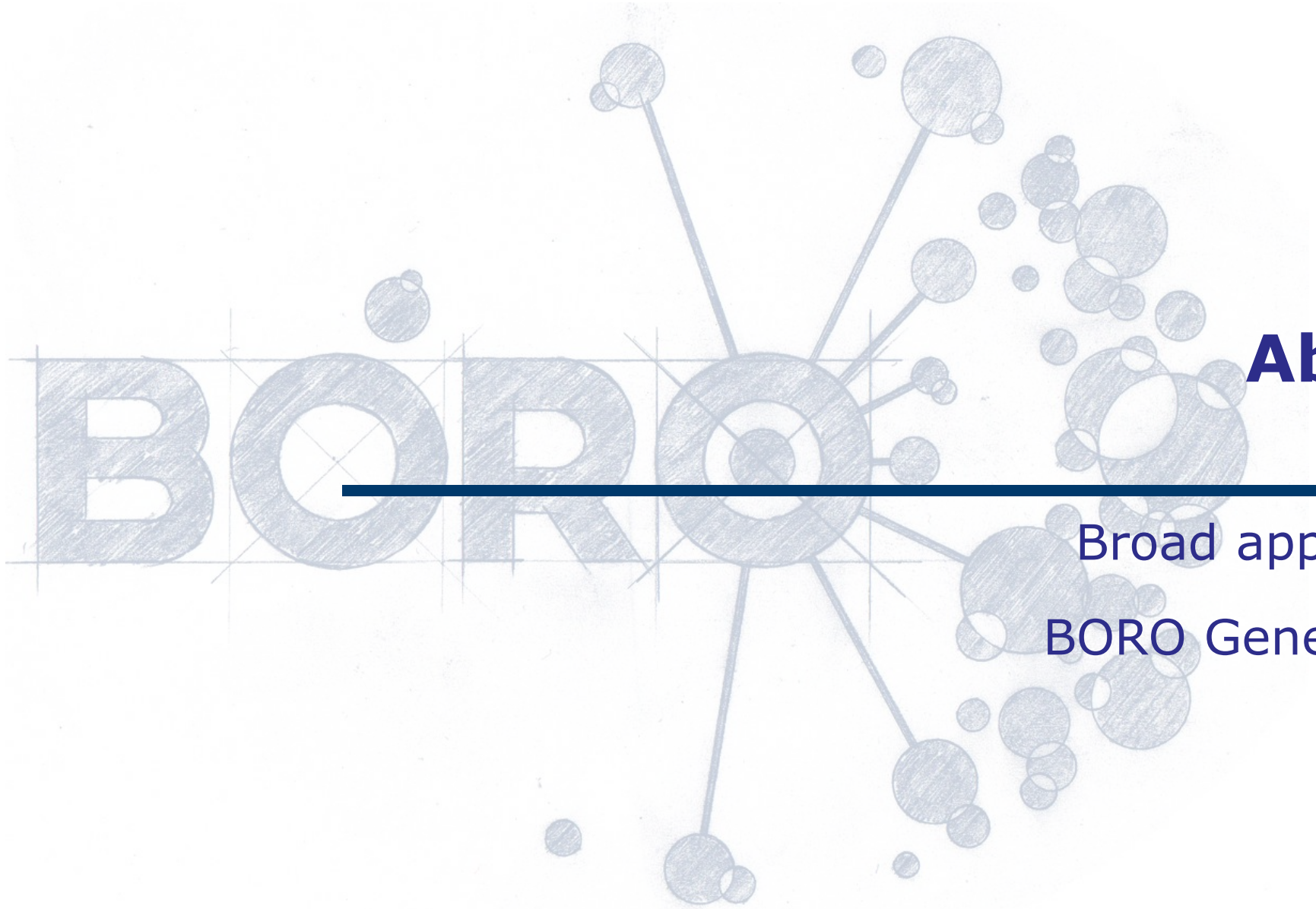
Structure

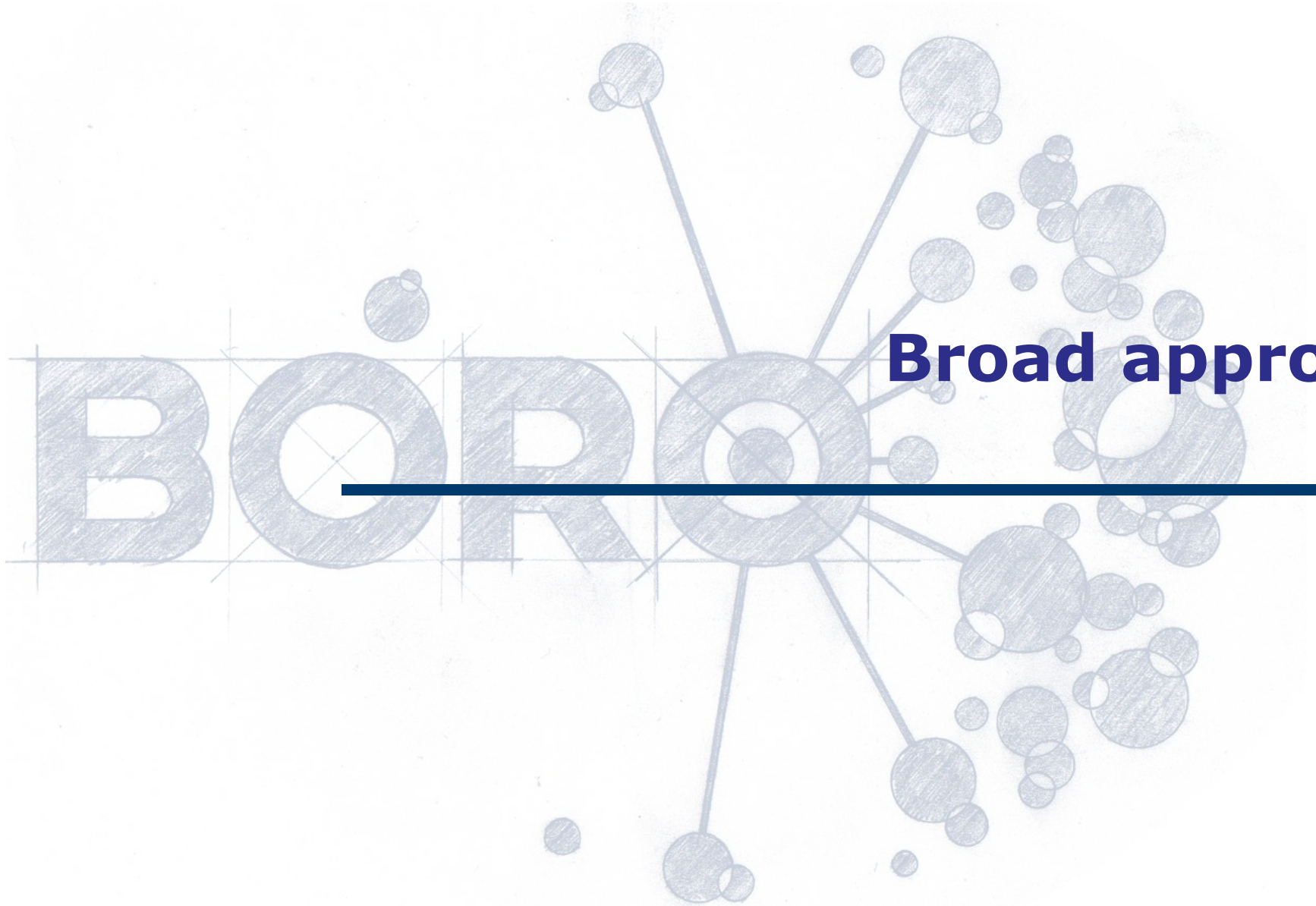
- About
  - Broad approach
  - BORO genealogy
- Characterising the BORO Foundational Ontology
  - Ontology – as ontological categories
  - Ontology – as everything that exists
  - Ontological architecture – as bricks in a wall
- Characterising the bCLEARer methodology



About

Broad approach

BORO Genealogy



Broad approach

Broad approach: tool or product

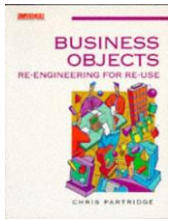
- One can broadly divide the ways in which ontologies (including foundational ontologies) can be promulgated into two:
  - **toolkit-based:**
    - toolkit for ontological analysis
      - does not preclude reuse of prior work (patterns)
        - in fact, it is encouraged
      - enables a flexible approach that can be tailored to each project
  - **product-based:**
    - pre-built reference ontologies
      - ontological analysis is done in advance – and packaged
      - a particularly strong version of this is: standard ontologies
        - aim to implement globally
        - raises concerns about premature standardisation
          - » See: Partridge, C. (2023). Avoiding premature standardisation: Balancing innovation and conformity. OntoCommons 2023, Second Global Workshop, Oslo, Norway.
- BORO has adopted the first approach - toolkit-based:
  - developing toolkits (including patterns) for ontological analysis
  - this does not exclude (as we shall see) the toolkit's use to develop product-based reference ontologies
- Motivation for this choice is agility
  - goal: to speed up evolution
    - allow the approach to be flexibly tailored to a variety of situations

BORO Genealogy

BORO genealogy

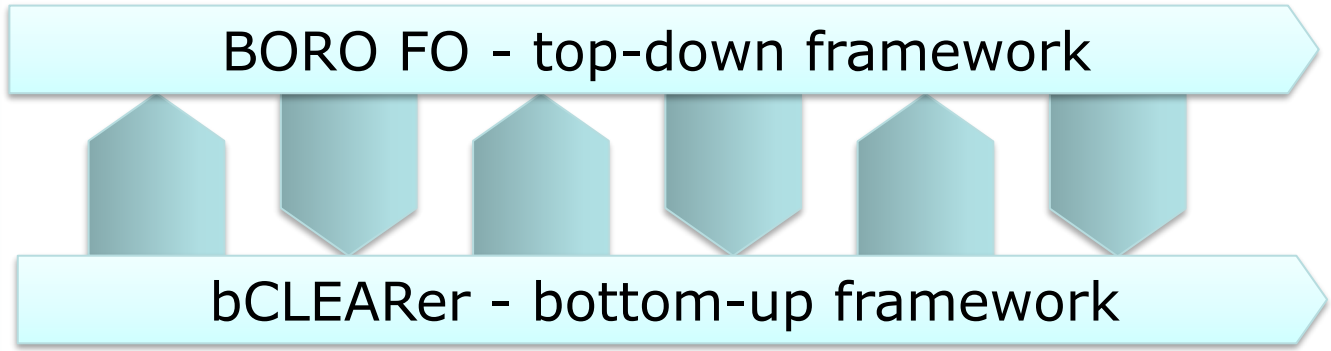
- 1. Introduction
- The Business Object Reference Ontology BORO has chosen to adopt a closer integration with philosophy than other ontologies in the information systems domain …
  - also, unlike them, **it emerged from and was developed in commercial projects rather than in academia**
- **BORO includes a foundational (or upper) ontology and a closely intertwined methodology for information systems (IS) re-engineering (Partridge, 1996),**
  - **hence the term BORO refers to both the ontology and the methodology.**
- **BORO was originally conceived in the late 1980s**
  - **to address a particular need for a solid legacy re-engineering process** and then evolved to address a wider need for developing enterprise systems in a 'better way';
  - in other words, in a way that … enable[ed] higher levels of reuse and, as a consequence, capable of reducing the effort and cost of (re-)developing, maintaining and interoperating enterprise systems. It was eventually publicly documented in (Partridge, 1996)

- *de Cesare, S. and Partridge, C. 2016. BORO as a Foundation to Enterprise Ontology. Journal of Information Systems. 30 (2), pp. 83-112. https://doi.org/10.2308/isys-51428*
- *Partridge, C. 1996. Business Objects: Re-Engineering for Re-Use, Butterworth-Heinemann.*

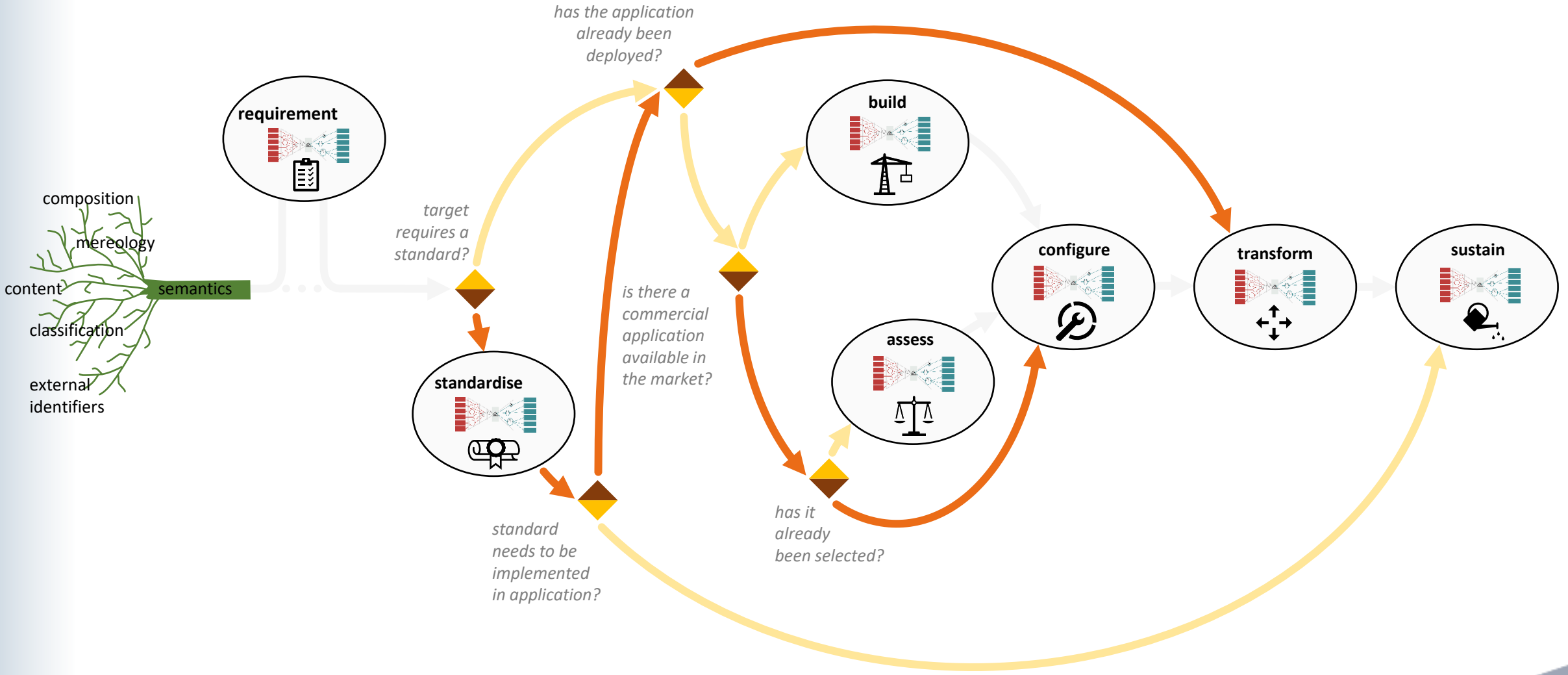


BORO components

- BORO has two closely intertwined components
  1. BORO Foundational Ontology
     - a foundational (or upper) ontology
  2. bCLEARer
     - a methodology systematically mining (re-engineering) the semantics from information systems
- The two frameworks validate and inform each other
  - top-down BORO Foundational Ontology guides the bottom-up framework
  - bottom-up bCLEARer framework validates the whole model

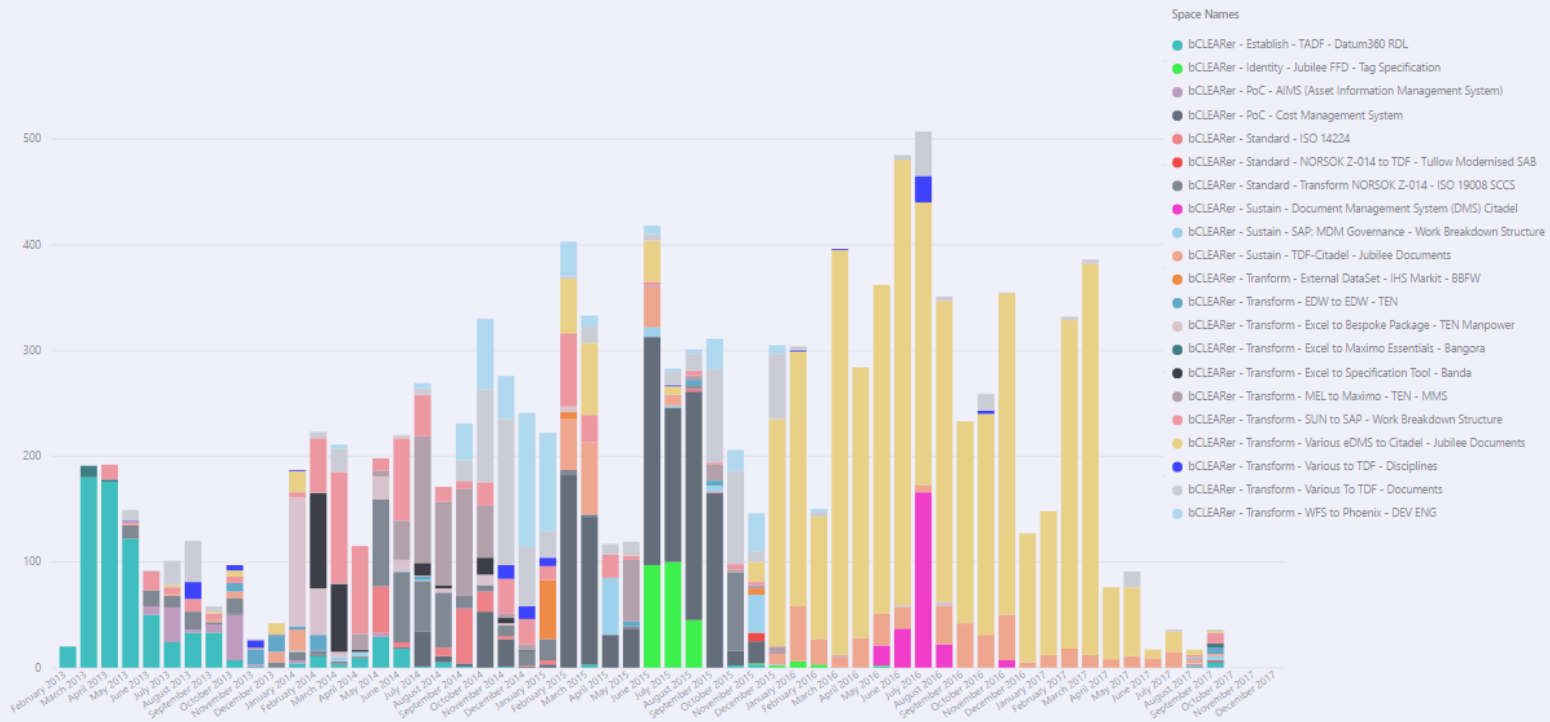


Toolkit can be deployed across various exploitation routes



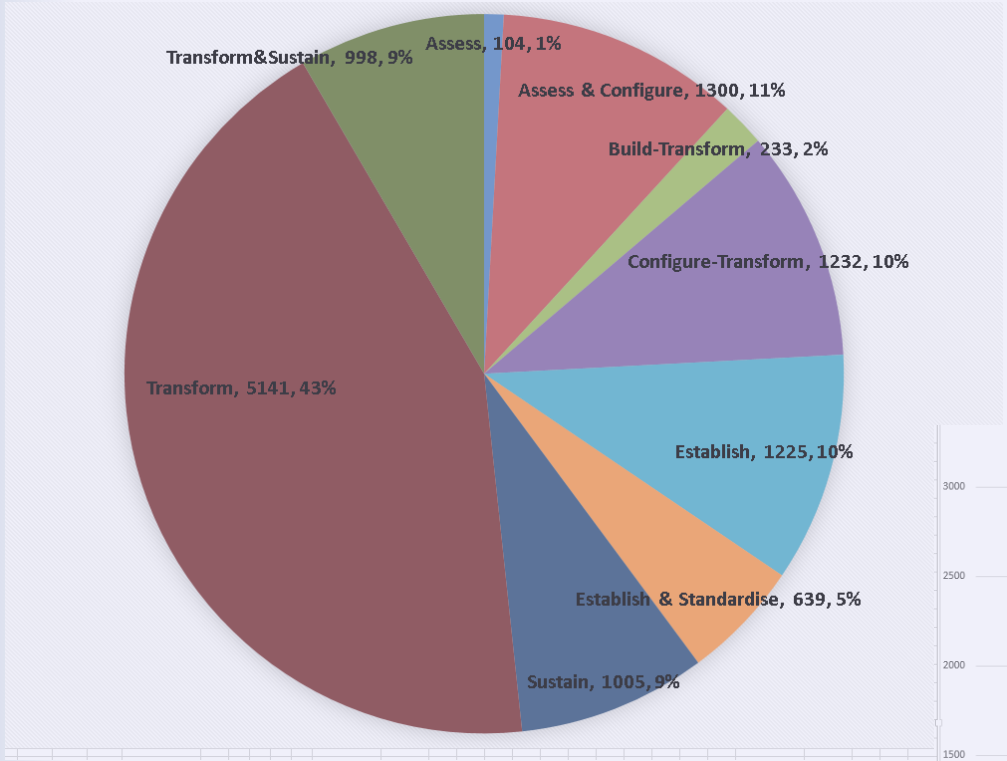
Business Object Reference Ontology

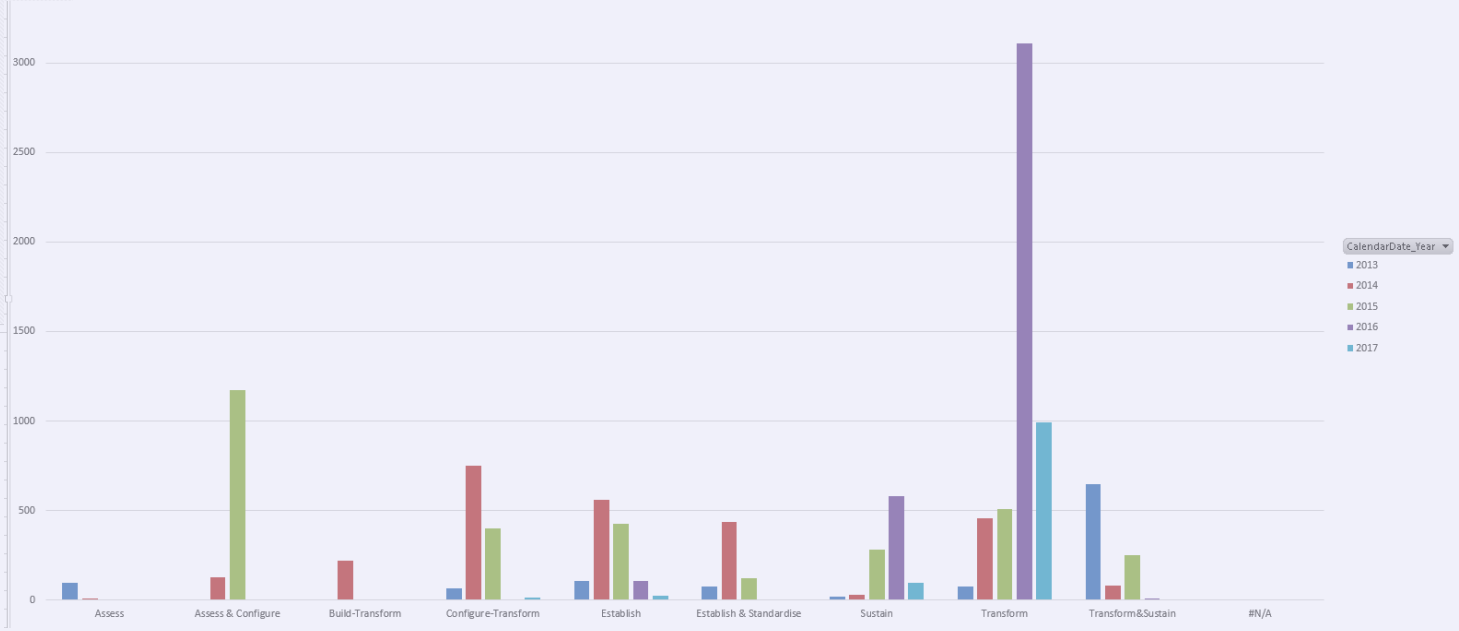
Example programme: analysis of effort



See: Partridge, C. (2017, December 8). *Dagstuhl Commercial Introductions—BORO Solutions*. Dagstuhl Seminar 17492 Multi-Level Modelling, Dagstuhl, Germany.

Example programme: work package type

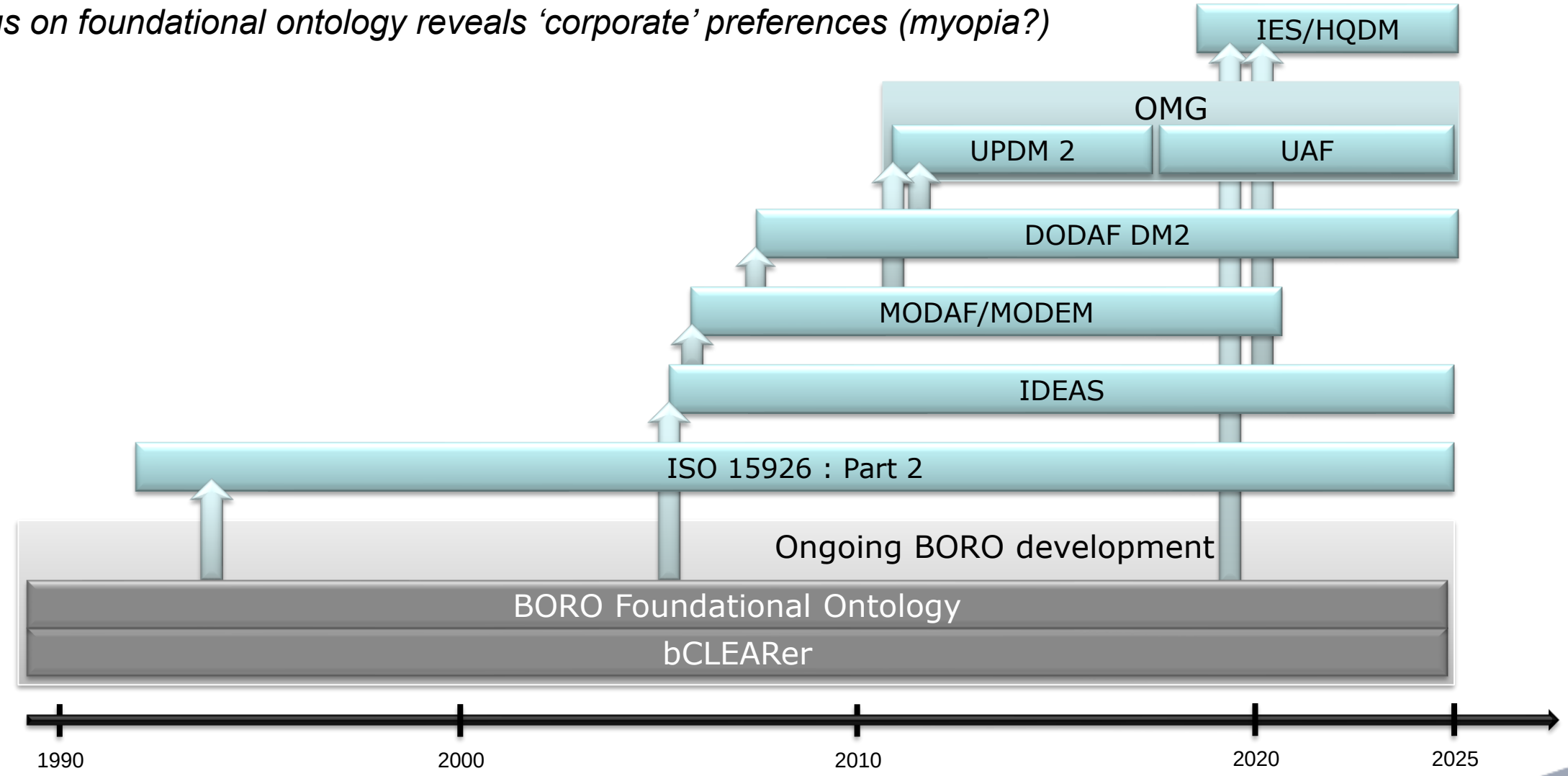


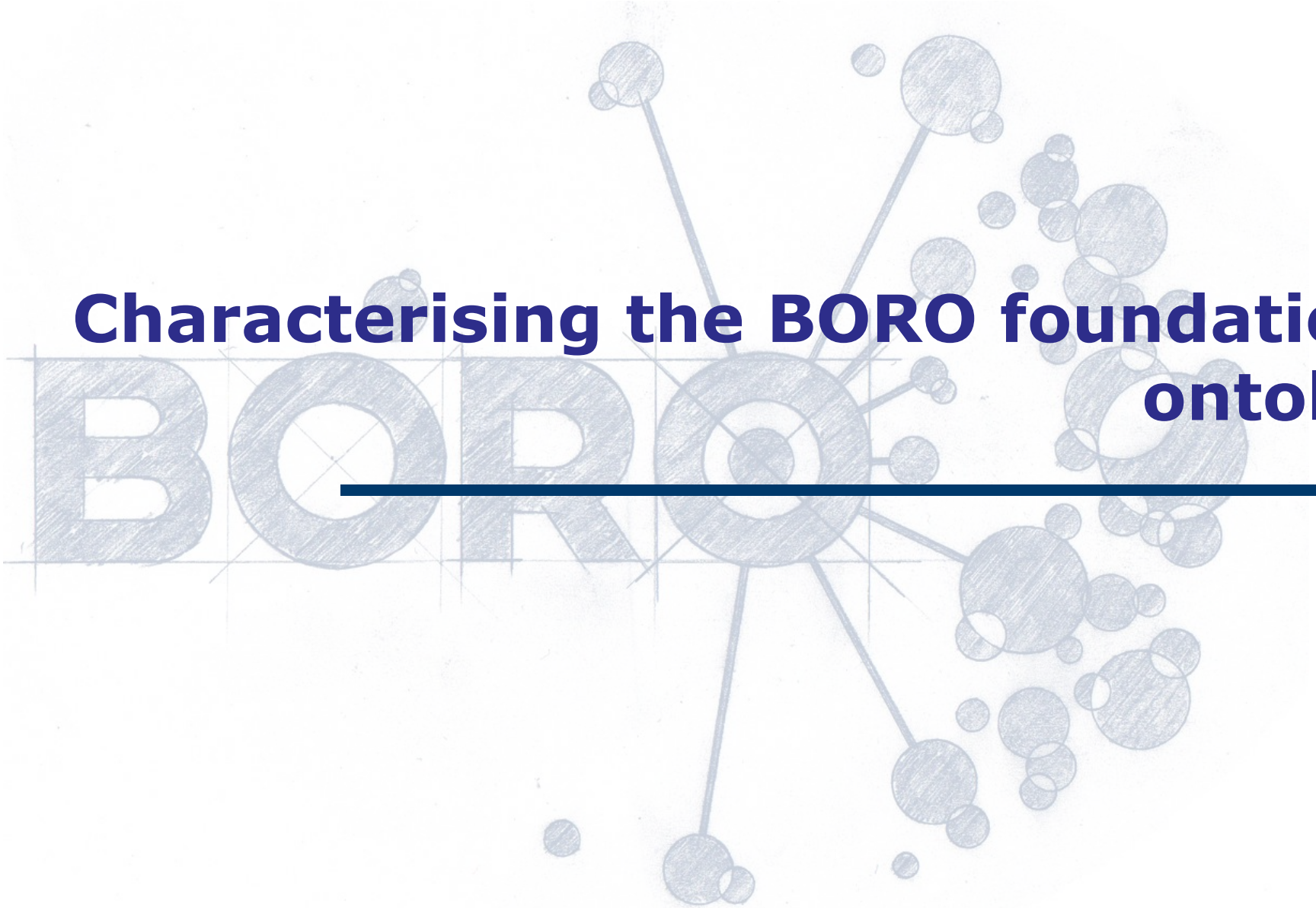


ce: Partridge, C. (2017, December 8). *Dagstuhl Commercial Introductions—BORO Solutions*. Dagstuhl Seminar 17492 Multi-Level Modelling, Dagstuhl, Germany.

Using BORO tools to develop reference models

Mapping interest in the standards community:
focus on foundational ontology reveals 'corporate' preferences (myopia?)





Characterising the BORO foundational ontology

Characterising the BORO foundational ontology

- Three ways
  - ontological categories
  - bare Quinean structure
  - broad ontological architecture (and patterns)

Ontology – as ontological categories

An ontology is *a* specification of the ontological categories

- Ontological categories have along history in ontology
  - recent example
- "It is a commonplace that the word 'ontology' is used both as a mass term and a count noun. When it is used as a mass term, it denotes a certain discipline, a certain subfield of philosophy or of metaphysics — just that discipline that I have been attempting to give an account of. When it is used as a count noun, it is used to refer to certain philosophically interesting answers to the ontological question. If my account of ontology is right, *an* ontology is *a* specification of the ontological categories or of some of the higher ones."
  - Van Inwagen, P. (2021). What is an Ontological Category? In *Disputatio* (Vol. 10, pp. 241–261).

BORO's ontological categories

- BORO has three ontological categories
  - Individuals
  - Sets
  - Tuples
- Everything that exists belongs to one and only one of these categories
- Each category is formally distinguished by its criterion of identity
  - all the criteria of identity are extensional
  - for more detail on BORO's approach to categories, see: Partridge, C. (2022). *Top-Level Categories: Categories for the Top-Level Ontology of the Information Management Framework. https://www.academia.edu/124916664/*

BORO's ontological categories' grounding relations

We look at these in more detail in the next section, when we look at construction.

foundational grounding relations

grounding relation	category place 1	category place 2
parts-wholes	individuals	individuals
elements-sets	objects	sets
tuple-places	(objects)	tuples

derived grounding relations

grounding relation	category place 1	category place 2
sub-super-sets	sets	sets

Each grounding relation is formally distinguished by its criterion of identity

Fine, K. (2010). Towards a Theory of Part: Journal of Philosophy, 107(11)

Ontological category: individuals

Individuals – Criterion of Identity

- Takes individuals as mereologically extensional
  - no two things can have exactly the same parts
    - (if two things have the same parts, they are the same thing)
- In the background is classical mereology

- See: Varzi, Achille, "Mereology", The Stanford Encyclopedia of Philosophy (Spring 2019 Edition), Edward N. Zalta (ed.), https://plato.stanford.edu/archives/spr2019/entries/mereology/.

Classical mereology

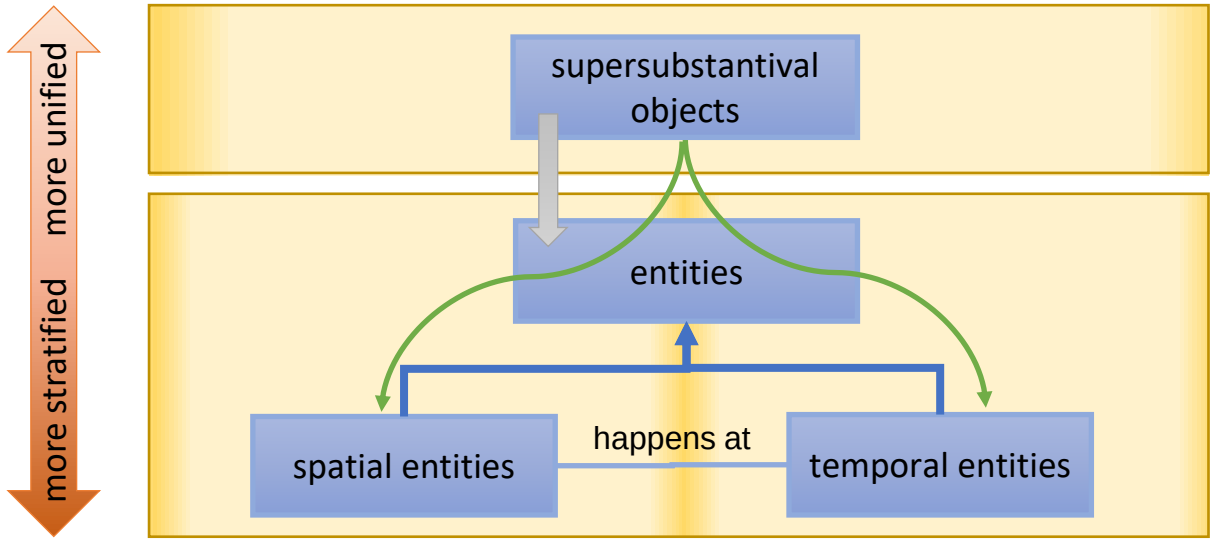
- Also called
  - Classical Extensional Mereology (CEM) or
  - General Extensional Mereology (GEM)
- Stems from the work of Leśniewski (1916, 1927–1931) and of Leonard and Goodman (1940)
  - formalisation is well understood – a standard
    - "This theory is by now well known and has been studied *axiomatically, algebraically*, and *set-theoretically*."
      - Cotnoir, A. J., & Varzi, A. C. (2021). *Mereology* (1st ed.). Oxford University Press. https://doi.org/10.1093/oso/9780198749004.001.0001
    - also see: Florio, S., & Linnebo, Ø. (2022). *Core Constructional Ontology: The Foundation for the Top-Level Ontology of the Information Management Framework*.
- Accepts Universalism
  - (also known as Conjunctivism, or Collectivism)
  - the thesis that mereological composition is unrestricted.
    - given any collection of individuals, then their mereological fusion also exists
    - this entails Extensionalism

Commitment to mereological extensionalism

- Has structure
  - For example, (Mereological) Universalism entails Extensionalism
- Extensionalism is the thesis that sameness of composition is sufficient for identity. More precisely:
  - (E) No two things have exactly the same proper parts (unless they are atomic, i.e., have no proper parts at all)
- Universalism (also known as Conjunctivism, or Collectivism) is the thesis that mereological composition is unrestricted. More precisely:
  - (U) Any non-empty collection of things has a fusion, i.e., something that has all those things as parts and has no part that is disjoint from each of them.
- Clearly these two theses are not equivalent. They are, however, more closely related than one might think. For while (E) does not entail (U), the converse entailment holds
  - Varzi, A. C. (2009). Universalism entails Extensionalism. Analysis, 69(4), 599–604. https://doi.org/10.1093/analys/anp102

Fleshing out individuals

This involves looking at the ontological choices



web-based: https://digitaltwinhub.co.uk/a-survey-of-top-level-ontologies/#a_survey_of_TLOs_contents

One iconography for stratification:
(see details in survey paper)

Stratification: 4D Ontologies' unifying choices

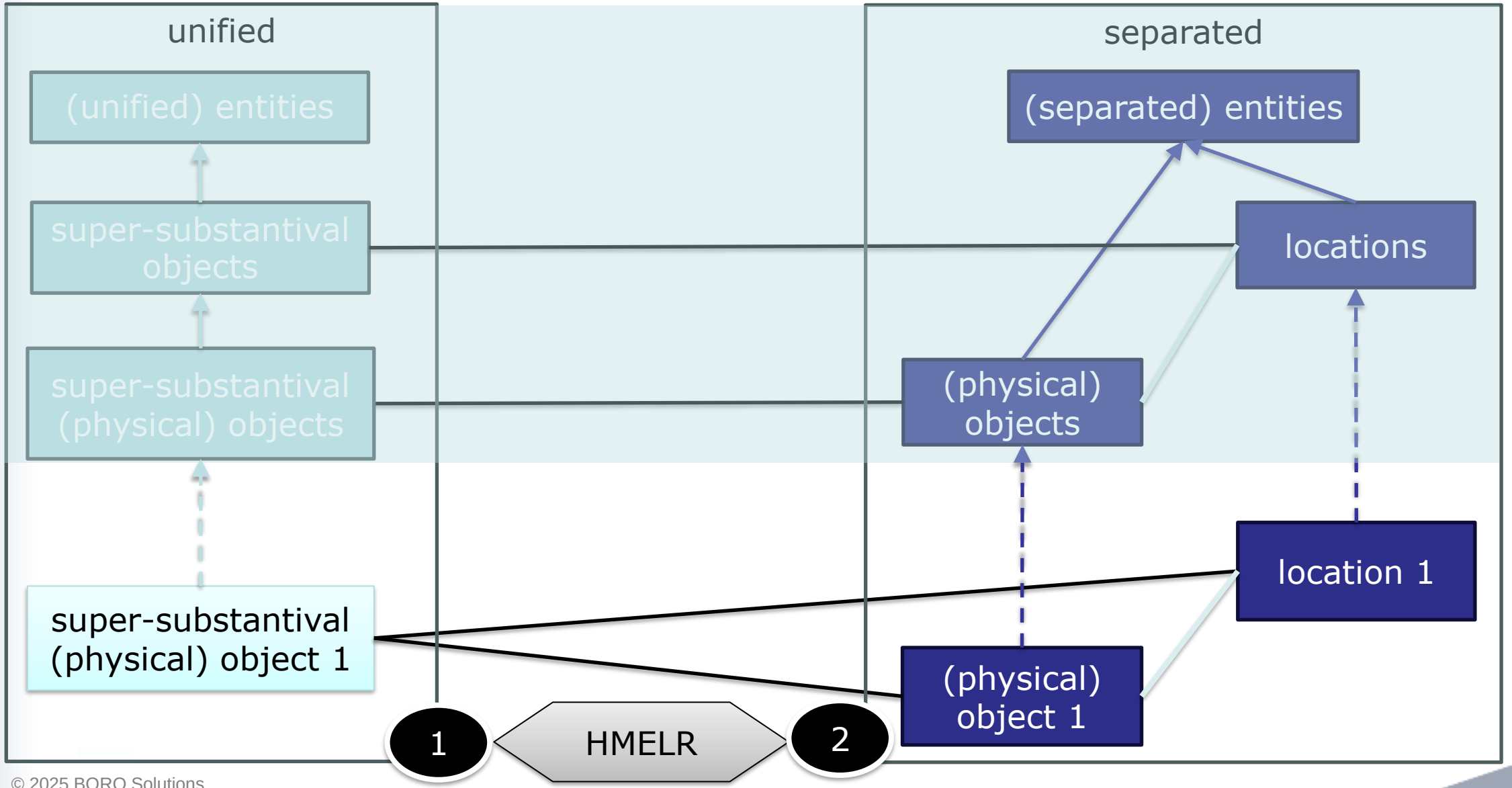
The BORO Foundational Ontology is a '4D Ontology'
4D Ontologies' unifying choices detailed in top level survey
As we know, some choices multiply entities, others reduce them.
One thing that characterizes 4D Ontologies is that they are (from the framework perspective) maximally unifying.

category	type	choice	4D Ontologies
stratification	space-time	unifying or separating	unifying
	locations-objects	unifying or separating	unifying
	properties-objects	unifying or separating	unifying
	endurants-occurrents	unifying or separating	unifying
	immaterial-material	unifying or separating	unifying

Motivation:

- the presumed benefits of parsimony and cost of separation.
- No loss of ability to support information requirements.

Recall: locations example - HMELR test



Additionally - possible worlds

- "4.3.5 Possibilia: actual or possible worlds
  - ... The TLO needs to provide an account of such objects. In this regard, there is traditionally one major choice to be made. This is whether to limit existence to the actual world or allow it to range over (all) possible worlds.
  - If one adopts a possible worlds approach, then talk of possible objects becomes talk about objects in possible worlds. The possible meeting that did not happen in this world happened in some other possible world. The planned building that was not built in this actual world was built in some other possible world. If one restricts oneself to the actual world, one needs to develop alternative explanations for these objects."
- In BORO's approach, individuals are the (up to) four-dimensional extensions across all possible worlds

4-Dimensionalism Background

See also: West, M. (2021, April 22). The Basics of 4-Dimensionalism and the Role it Can Take in Supporting Large Scale Data Integration. https://borosolutions.net/basics-4-dimensionalism-and-role-it-can-take-supporting-large-scale-data-integration

The original 3D position

As with many things, started with the Ancient Greeks
– and lasted over a millennia.

Author	Document	Comment
Aristotle	On the Heavens	a solid has magnitude "in three ways and beyond these there is no other magnitude because the three are all."
	Physics [IV, 1]	in the context of motion, there are six "dimensions", dividing each of the three into two opposites, "up and down, before and behind, right and left," these terms being taken relatively.
Simplicius	Simplicii in Aristotelis De Caelo Connnentaria	notes "it is possible to take only three lines that are mutually perpendicular, two by which the plane is defined and a third measuring depth so that if there were any other distance after the third it would ne entirely without measure and without definition."
John Wallis	Treatise of Algebra (1685)	“For Length, Breadth and Thickness, take up the whole of Space. Nor can our Fansie imagine how there should be a Fourth Local Dimension beyond these Three.”

Early appearances of 4D

Year	Author	Document	Comment
1754	D'Alembert	Encyclopedie Art. "Dimension	"… one may however look upon duration as a fourth dimension, and that the product of time and solidity is in a way a product of four dimensions
1788	Joseph-Louis Lagrange	Mécanique analytique	mechanics operating in a four-dimensional space — three dimensions of space, and one of time.
1827	A. F. Möbius	Der barycentrische Calcul	a fourth dimension would allow a three-dimensional form to be rotated onto its mirror-image
1854	Georg Friedrich Bernhard Riemann	On the hypotheses which underlie geometry	formalized higher-dimensional spaces
1880	Charles Howard Hinton	What is the Fourth Dimension?"	Explained what a "four-dimensional cube" is.

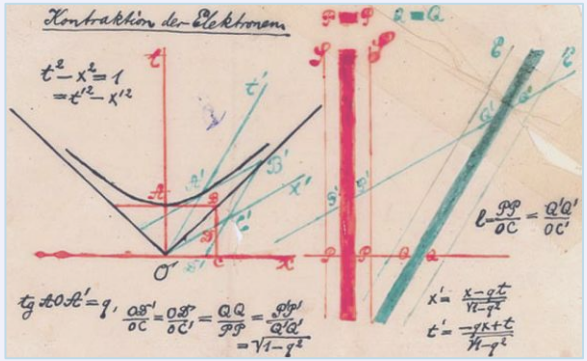
Cajori, Florian (1926). "Origins of Fourth Dimension Concepts". The American Mathematical Monthly. 33 (8): 397–406.

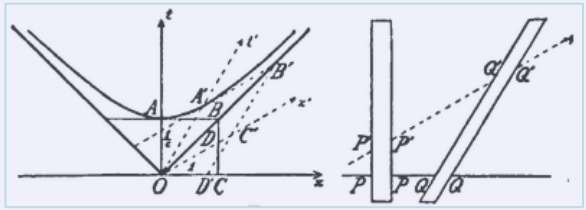
Origin of (geometric) four-dimensionalism

"Space and Time" address at 80th Assembly of German Natural Scientists and Physicians on 21 September 1908:

"The views of space and time which I wish to lay before you have sprung from the soil of experimental physics, and therein lies their strength. They are radical. Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality."

Hermann Minkowski





A brief history of the developments in four dimensionalism: selected major publications - I

The first half of the 20th century

Year	Author	Publications
1920	A. N. Whitehead	The Concept of Nature. Cambridge University Press, Cambridge.
1923	C. D. Broad	Scientific Thought. Harcourt, New York.
1927	B. Russell	The Analysis of Matter. Allen & Unwin, London.
1928	R Carnap	Der logische Aufbau der Welt. Weltkreis-Verlag, Berlin.
1928	H. Reichenbach	Philosophie der Raum-Zeit-Lehre, Walter de Gruyter, Berlin and Leipzig.
1937	J. Woodger	The axiomatic method in biology. Cambridge

A brief history of the developments in four dimensionalism: selected major publications - II

The second half of the 20th Century

Year	Author	Publications
1950	W.V.O. Quine	Methods of Logic. Holt, Rinehart & Winston, New York.
1951	N. Goodman	Goodman, N., The Structure of Appearance. Harvard University Press, Cambridge (MA).
1955	Taylor	Spatial and temporal analogues and the concept of identity. The Journal of Philosophy, 52: 599–612.
1955	J. J. C. Smart	Spatialising time. Mind, 64: 239–241.
1967	H. Putnam	Time and physical geometry, Journal of Philosophy 64 (8):240-247.
1971	D. K. Lewis	Counterparts of persons and their bodies. The Journal of Philosophy, 68: 203–211.
1972	J. J. C. Smart	Space-time and individuals. In Rudner, R. S. and Scheffler, I., eds., Logic and Art
1976	H. W. Noonan	The four-dimensional world. Analysis, 37: 32–39.
1980	H. W. Noonan	Objects and Identity. An Examination of the Relative Identity Thesis and Its Consequences. Nijhoff
1986	D. K. Lewis	On the Plurality of Worlds. Blackwell, Oxford.
1980	D. M. Armstrong	Identity through time. In van Inwagen, P., ed., Time and Cause.
1982	D. Robinson	Re-identifying matter. The Philosophical Review, 91: 317–341.
1984	M. Heller	Temporal parts of four dimensional objects. Philosophical Studies, 46: 323–334.
1990	M. Heller	The Ontology of Physical Objects: Four-dimensional Hunks of Matter. Cambridge University Press,
1990	P. van Inwagen	Four-Dimensional Objects, Noûs, 24: 245–55.
1993	M. Heller	Varieties of Four Dimensionalism, Australasian Journal of Philosophy,
1991	R. Le Poidevin	Change, Cause and Contradiction. A Defence of the Tenseless Theory
1993	M. Jubien	Ontology, Modality, and the Fallacy of Reference. Cambridge Universit

The 21st Century texts on four dimensionalism are too numerous to list here.

Ontological category: sets

Sets

- Takes set as extensional
  - standard set theory
    - In ZF, the axiom of extensionality
  - no two sets can have exactly the same elements
  - (if two sets have the same elements, they are the same set)
- No constraints on what can be used to build a set
  - objects belonging to any ontological category can be elements of sets
  - given any collection of objects, you can build a set
- Simple sets such as ‘persons’ have as elements all the (individual) persons in all possible worlds

Ontological category: tuples

Tuples

- Takes tuples as extensional
  - standard mathematical tuples
    - a mathematical tuple is an ordered sequence of objects
      - unlike sets, tuples are ordered, meaning (a, b) is distinct from (b, a), and they allow duplicate objects – so (a, a) is tuple.
      - the "place" of an object refers to its position in that sequence.
  - no two tuples can have exactly the same objects in the same places
    - (i.e. in the same order)
  - (if two tuples have the same objects in the same places, they are the same tuple)

- No constraints on what can be used to build a tuple
  - objects belonging to any ontological category can be placed in a tuple
  - given a collection of objects can be placed in order in a tuple

Ontology – as everything that exists

Bare Quinean view

“Bare Quinean” ontology - everything

- Returning to van Inwagen’s paper
- “There is, secondly, what I will call the “**bare Quinean**” conception of ontology. Quine has famously called the question ‘What is there?’ “the ontological question,” and one might incautiously infer from this label that he conceives of ontology as the attempt to answer the ontological question. … Quine himself has observed that one correct answer to the ontological question is ‘Everything’ — and we certainly do not need to turn to any science or discipline to satisfy ourselves that that answer is correct.”
  - Van Inwagen, P. (2021). What is an Ontological Category? In *Disputatio* (Vol. 10, pp. 241–261).

Ontology as ‘everything that exists’

- “A curious thing about the ontological problem is its simplicity. It can be put in three Anglo-Saxon monosyllables: **‘What is there?’** It can be answered, moreover, in a word—**‘Everything’**—and *everyone will accept this answer as true*. However, this is merely to say that there is what there is. There remains room for disagreement over cases; and so the issue has stayed alive down the centuries.”
  - Quine, W. V. (1948). "On What There Is". Review of Metaphysics. 2: 21–38.
- “the **set of things** whose existence is acknowledged by a particular theory or system of thought.”
  - Lowe, E. J. (1995). Ontology. In T. Honderich (Ed.), The Oxford companion to philosophy. Oxford University Press.

BORO constructional '*bare Quinean*' foundation

- BORO's adoption of the constructional approach enables it to answer the '*bare Quinean*' question
  - To specify everything that exists
- It also neatly 'explains' the three ontological categories
  - And the foundational grounding relations

History

Contructionalism is not new. It has a longish history in philosophy in the twentieth century.

Carnap	1928	Der Logische Aufbau der Welt
Goodman and Quine	1947	Steps Toward a Constructive Nominalism
Goodman	1956	A World of Individuals
Goodman	1958	On Relations that Generate
Gödel	1964	What is Cantor's Continuum Problem
Boolos	1971	The iterative conception of set

More recently new ideas from Kit Fine have given a fresh impetus to constructional ontology

Fine	1991	The Study of Ontology
Fine	2002	The Limits of Abstraction
Fine	2005	Our Knowledge of Mathematical Objects
Fine	2010	Towards a Theory of Part

BORO constructional history

Stage	Year	Publication
Establish 2014-16	2016	BORO as a Foundation to Enterprise Ontology
Deploy 2017-21	2017	Developing an Ontological Sandbox
	2019	Coordinate Systems: Level Ascending Ontological Options
	2020	The Fantastic Combinations and Permutations of Co-ordinate Systems' Characterising Options
	2021	A Framework for Composition
Roll out 2020-24	2020	The Approach to Develop the Foundation Data Model for the Information Management Framework
	2022	Core Constructional Ontology
	2024	The ToLO IES5 Report

Constructionalism: shifting the way an ontology is 'defined'

Kit Fine: *The Study of Ontology*: "… , it is possible to define when three collections E, B, and C constitute an acceptable ontology (with E comprising the elements, B the basic elements, and C the constructors). "

An ontology may be constructional. Some of the objects of the ontology are accepted (i.e. included within the ontology) on the grounds that they are constructed from other objects within the ontology; it is their status as constructs which earns their admission into the ontology.

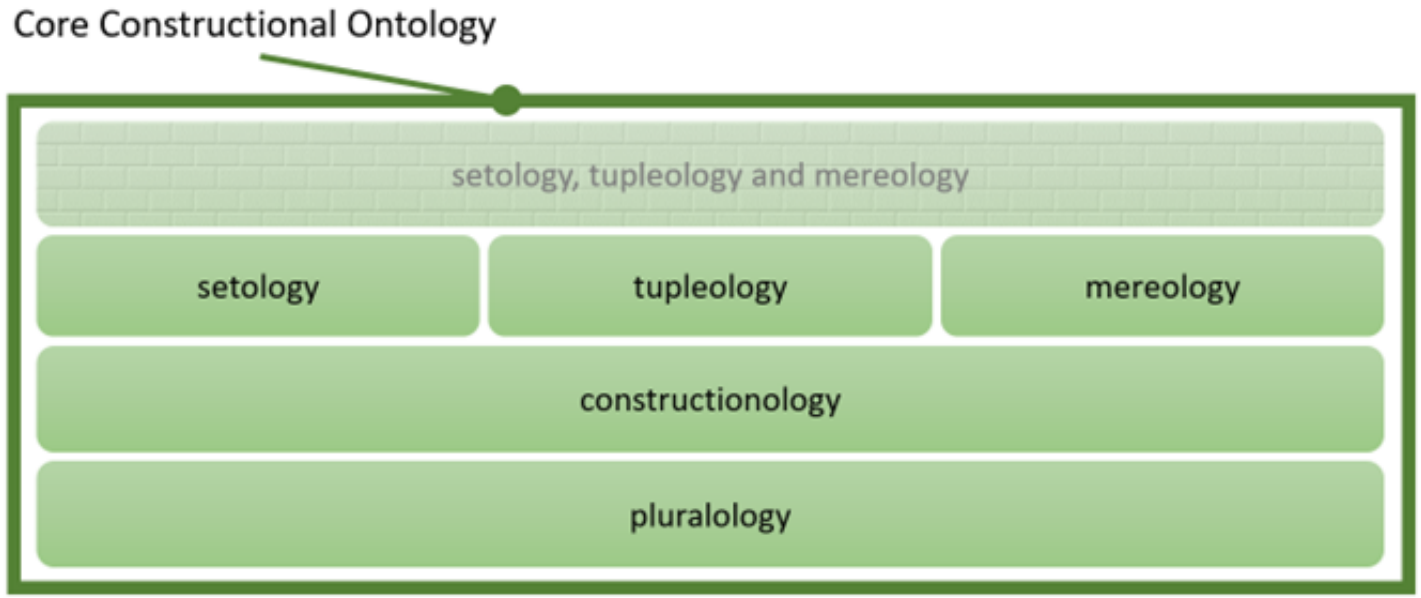
The objects which are accepted into an ontology on the ground that they are constructed from other objects may be called constructs. The acceptance of a construct into an ontology therefore requires the acceptance of two other items. The first is its constructees, i.e. the objects from which it is constructed. The second is the constructor, i.e. the means by which the construct is constructed from the constructees. The constructor must be regarded as a legitimate means of constructing one object from others.

We therefore see that a constructional ontology has a tripartite structure; there are domains for the elements, for the givens, and for the constructors. We have previously used the term 'ontology' for the domain of its elements. But let us henceforth reserve the term for the full tripartite structure and use the alternative term 'ontological domain' for the domain of elements.

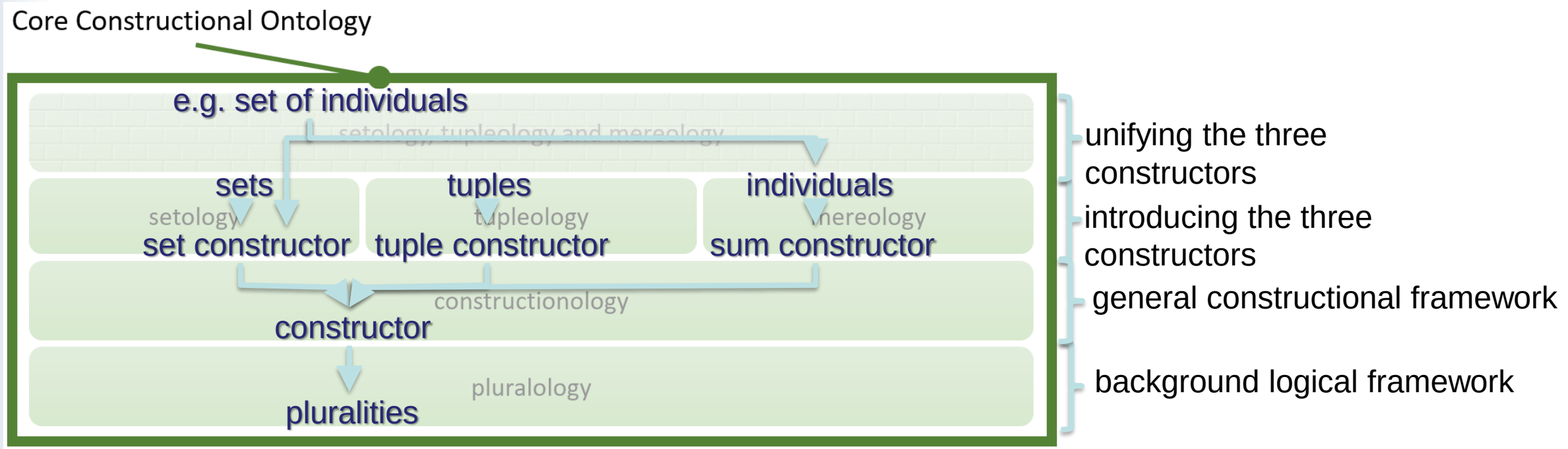
Where E the elements are generated from B, the basic elements using C, the constructors.
So, B and C are fundamental, E is derived.

An example of foundational parsimony - see: J. Schaffer, 'What not to multiply without necessity',

Core Constructional Ontology (CCO)



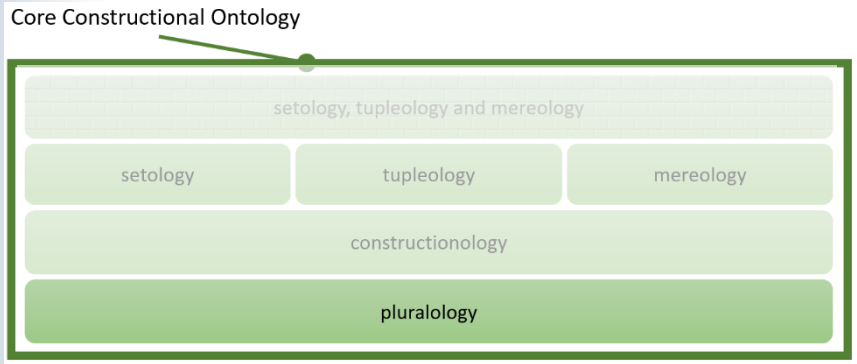
CCO – components



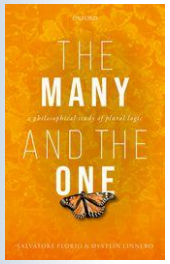
See:

- *Core Constructional Ontology: The Foundation for the Top-Level Ontology of the Information Management Framework*
- *Top Level Categories: Categories for the Top-Level Ontology of the Information Management Framework*

Pluralology – the logical framework

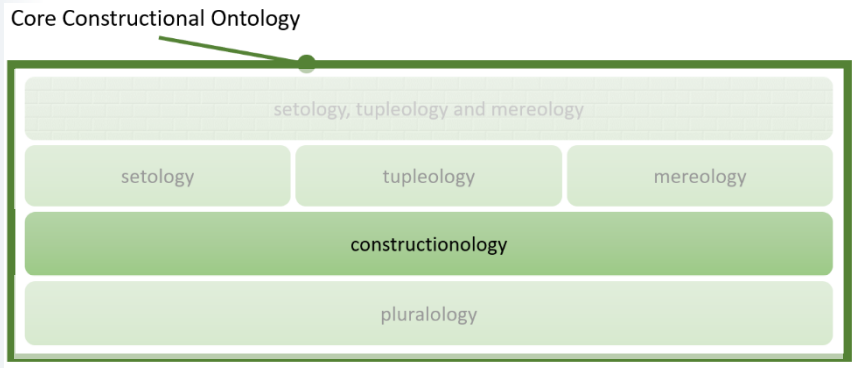


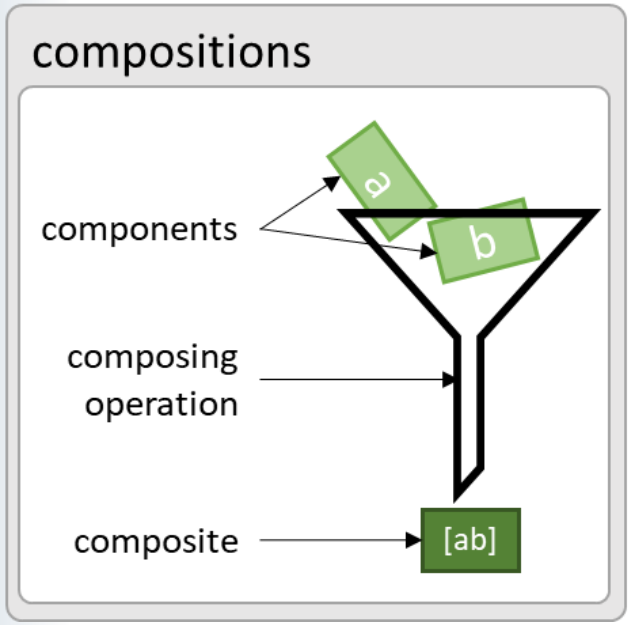
- pluralology is based upon ***pluralities***
- pluralities are distinct from objects
- pluralities are collections of objects
  - objects are their members
- pluralities can have sub-pluralities
  - where every member of the sub-plurality is also a member of the super-plurality
- pluralities are extensional
  - if two pluralities collect the same objects,
  - then they are the same plurality
- *looking ahead* – pluralities are the inputs to constructors

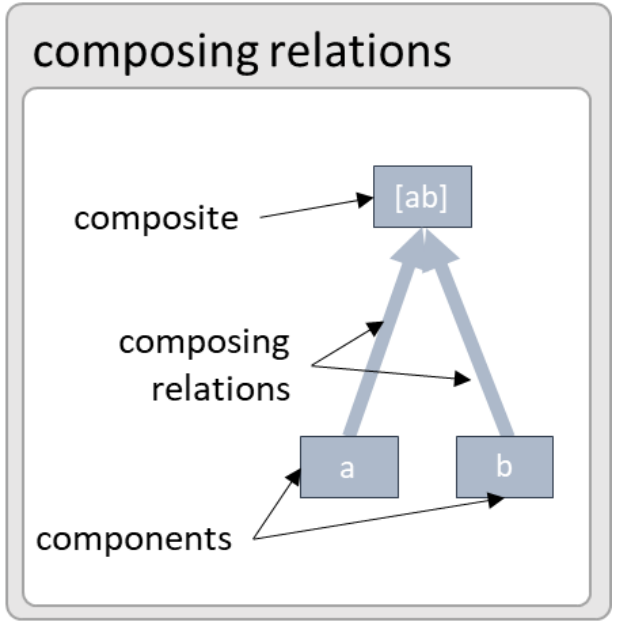


See: *The Many and the One: A Philosophical Study of Plural Logic, Salvatore Florio & Øystein Linnebo. (2021)*

Constructionology – the general framework

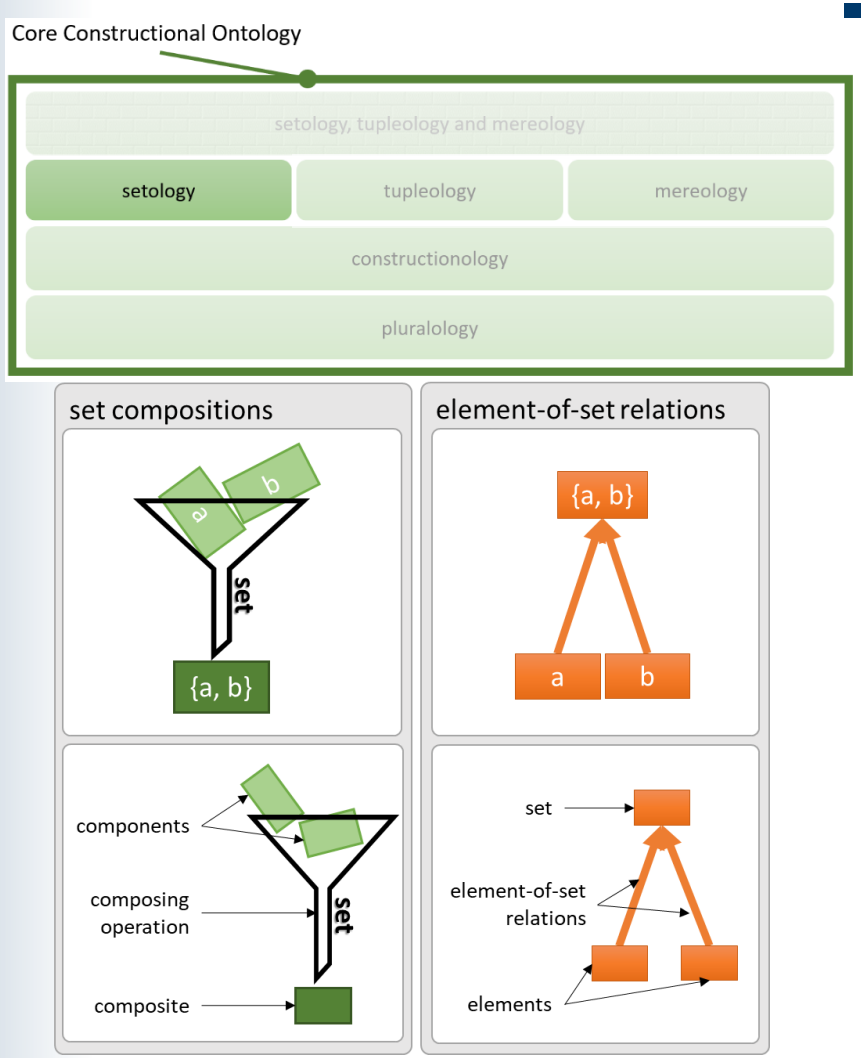






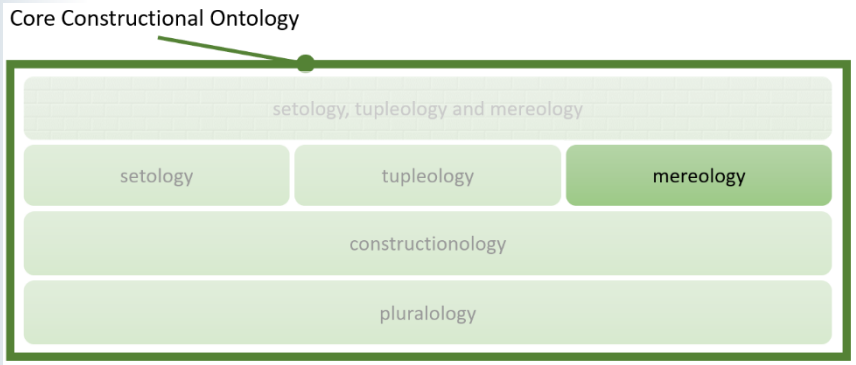
- a general framework for constructors
- constructors take pluralities of objects (the components) as inputs and construct a new object (the composite)
- this gives rise to composing relations.
- these composing relations are ontologically ‘dependence’ or ‘grounding’ relations.

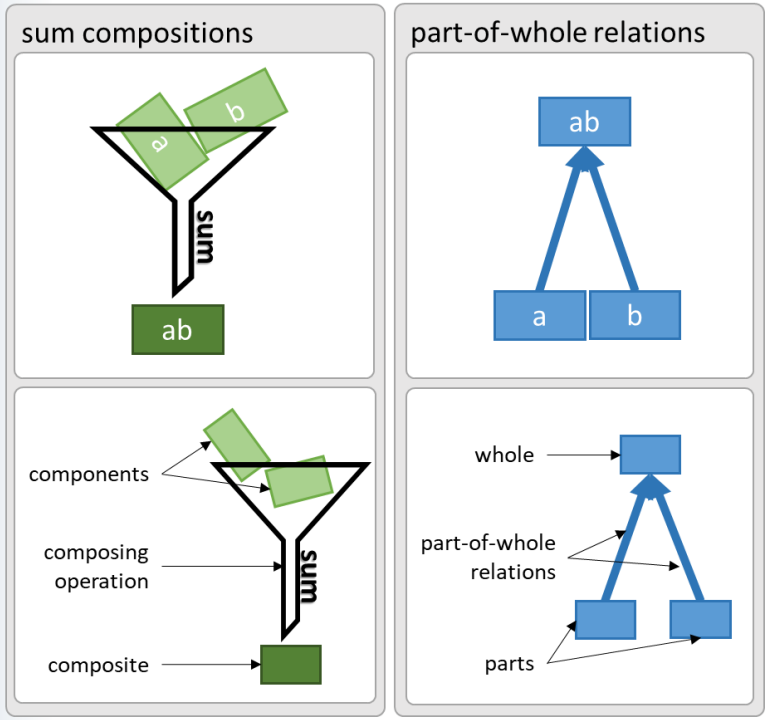
Setology (module)



- setology is built using the set constructor
- this constructs sets from pluralities of objects
- it also gives rise to the element-of-set relation
  - members of the plurality are elements of the constructed set
- identity (extensional): two sets are the same if they have the same elements.
- the plurality of sets is the plurality of all objects constructed by the set constructor.

Mereology (module)



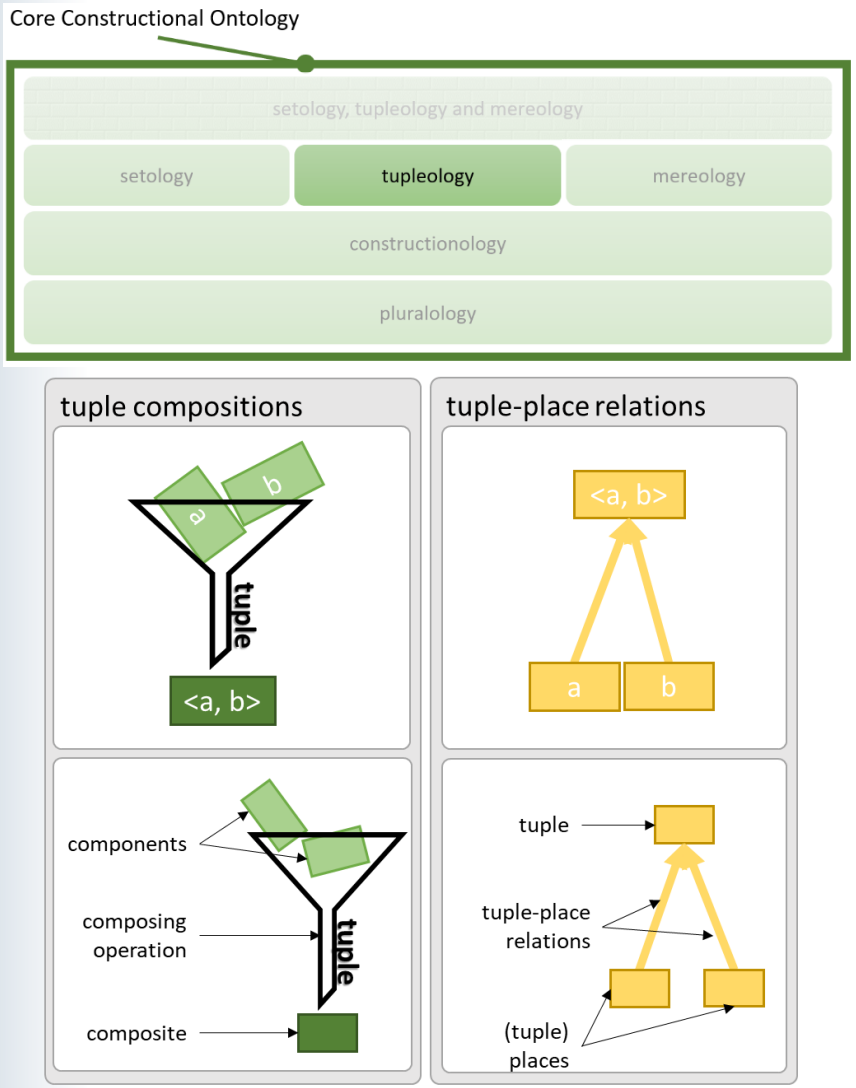


- mereology is built using the sum constructor
- this constructs individuals from pluralities of individuals
- it also gives rise to the part-of-whole relation
  - members of the plurality are part of the constructed individual
- identity (extensional): two individuals are the same if they have the same parts.
- the plurality of individuals is the plurality of all objects constructed by the sum constructor.

- mereology starts from the givens: these are the mereological simples (atoms)

- mereology can also be built using the sum deconstructor
- this deconstructs individuals into pluralities of individuals
- it also gives rise to the part-of-whole relation

Tupleology (module)

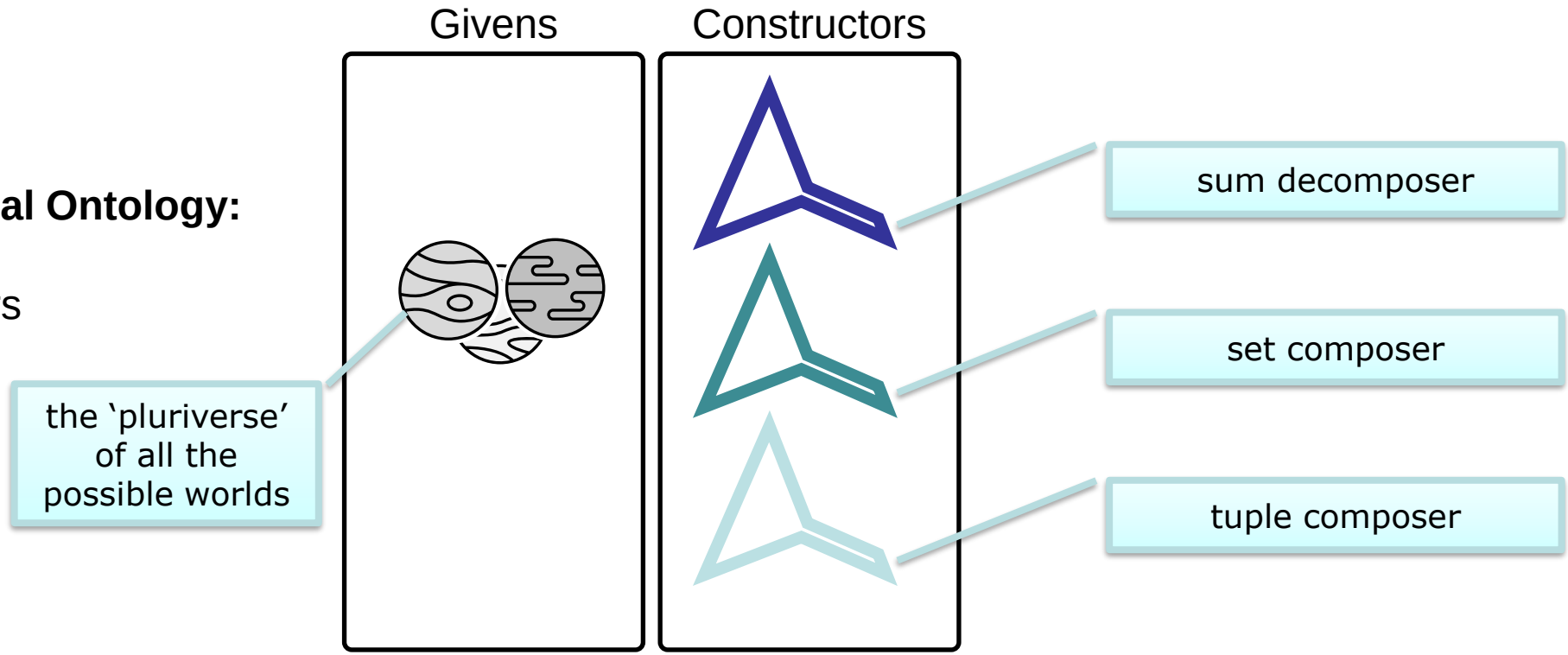


- tupleology is built using the tuple constructor
- this constructs tuples from pluralities of objects
- it also gives rise to the tuple-place relation
  - members of the plurality occupy tuple-places in the constructed tuple
- identity (extensional): two tuples are the same if they have the same tuple-placed objects in the same tuple-places.
- the plurality of tuples is the plurality of all objects constructed by the tuple constructor.

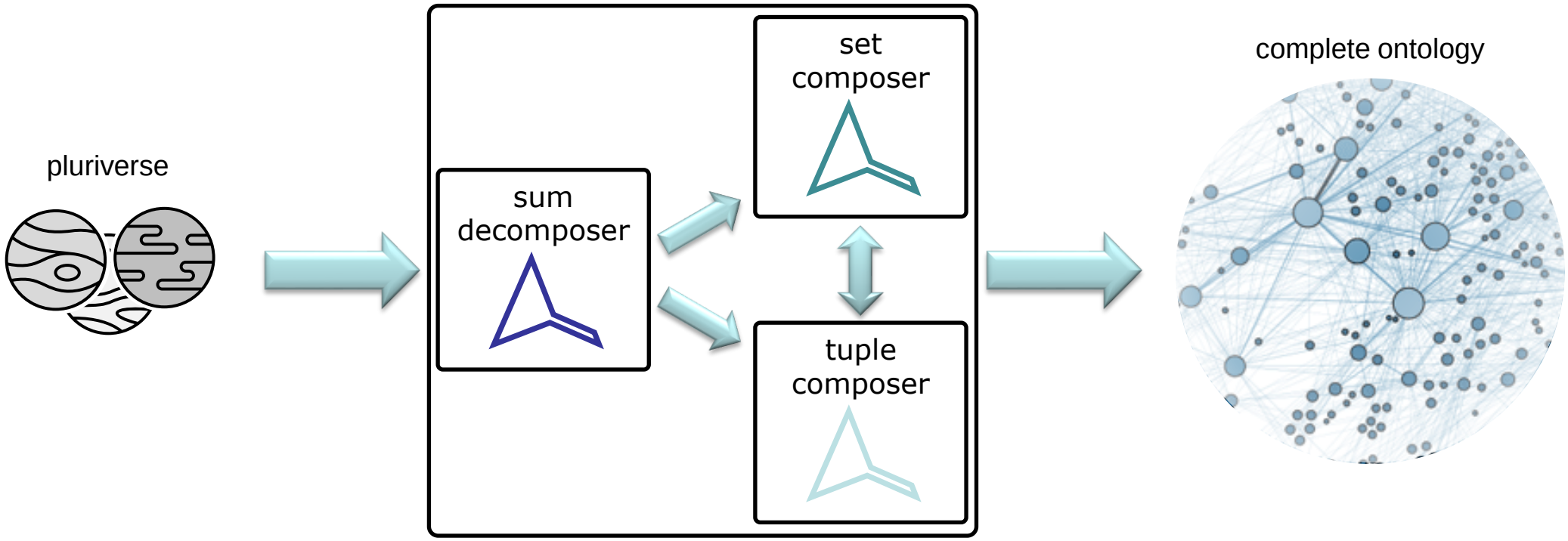
BORO as a constructional ontology

General principle:
Define any constructional ontology with 2 types of things:
1. givens and
2. constructors

BORO Foundational Ontology:
- one given;
- three constructors



Whole ontology constructed from a single object



Key aspects of the CCO approach

Foundational		Unifying		Constructional	
Object completeness	The construction process supplies all the objects	Common emergence of categories	All the categories (sets, individuals, tuples) arise through construction	Dependency (Grounding)	Construction implies dependence
Categorical completeness	It also supplies the categories and their associated hierarchical relations	Common basis for identity criteria	Identity criteria arise through construction, with differences arising from the way they are constructed	Parsimony (Reduction)	Built from a small set of fundamental objects
Common identity criteria	It also determines the identity criteria (extensional based on the type of constructor and its input)	Uniform commonalities and differences	Commonalities and differences between categories captured by features of the underlying constructors	Consistency	Construction can be a basis for consistency

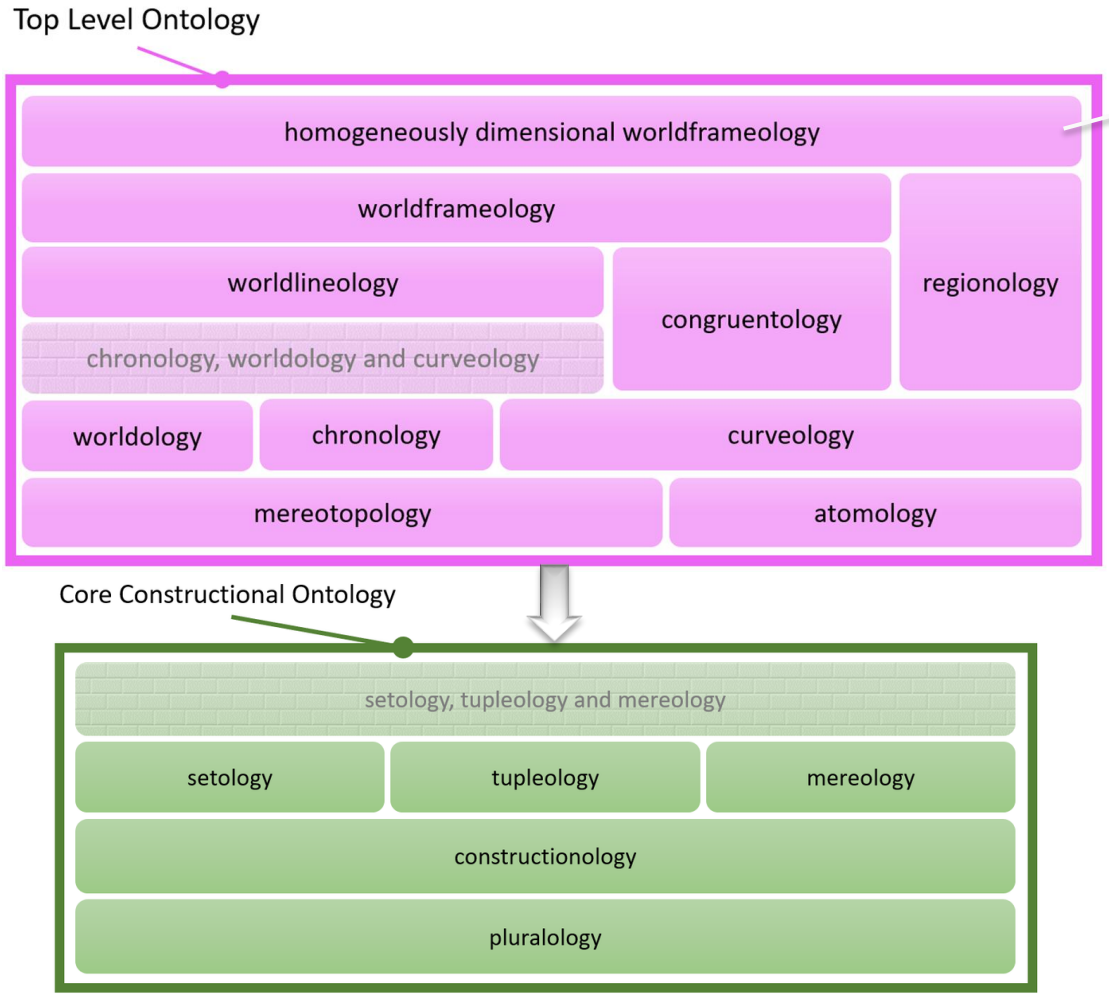
See: *Core Constructional Ontology: The Foundation for the Top-Level Ontology of the Information Management Framework*

Ontological architecture – as bricks in a wall

Key points

- Propose the BORO TLO deals with formal structures
  - such as topological/metric structures

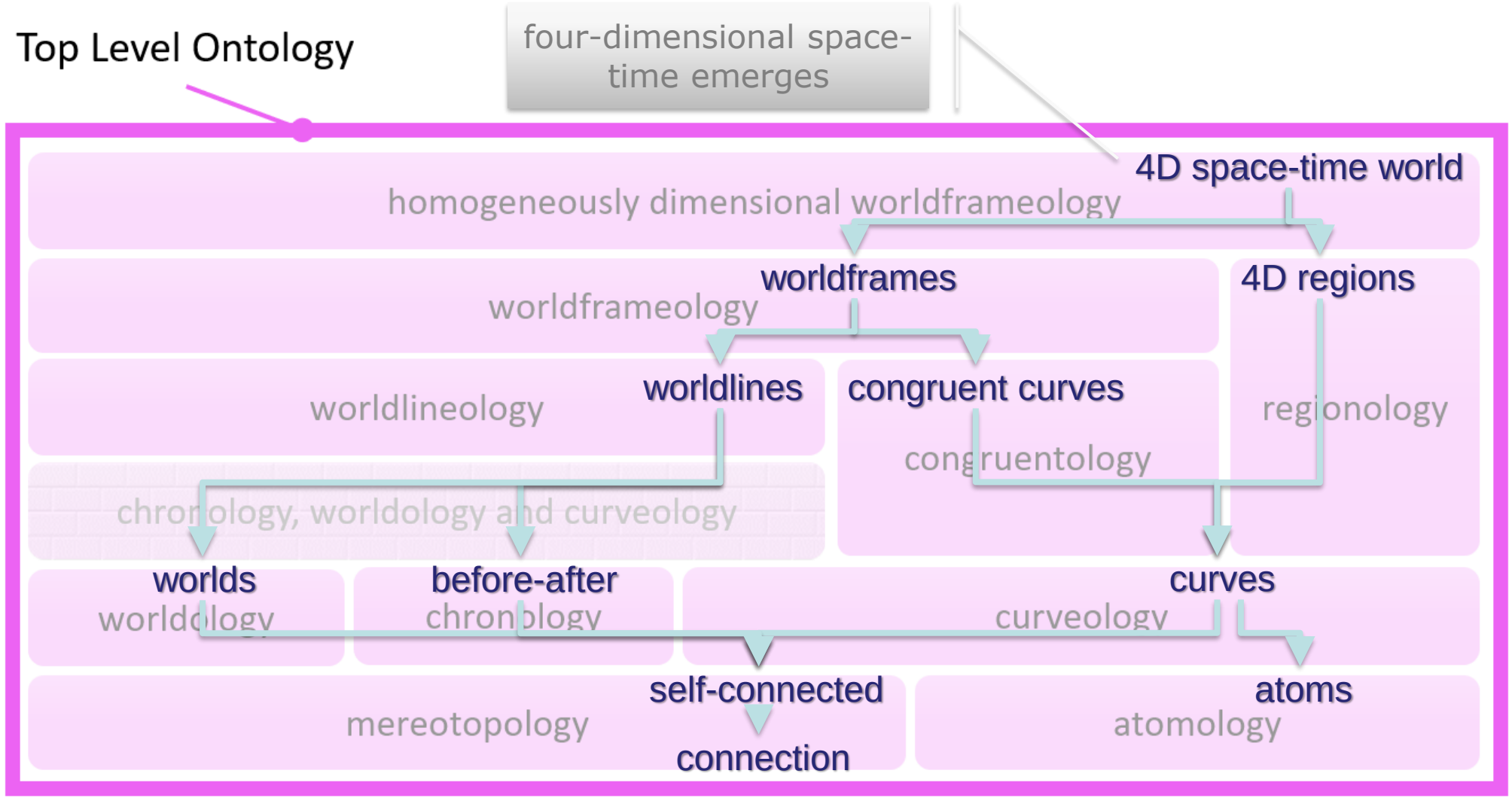
The data sections' data components



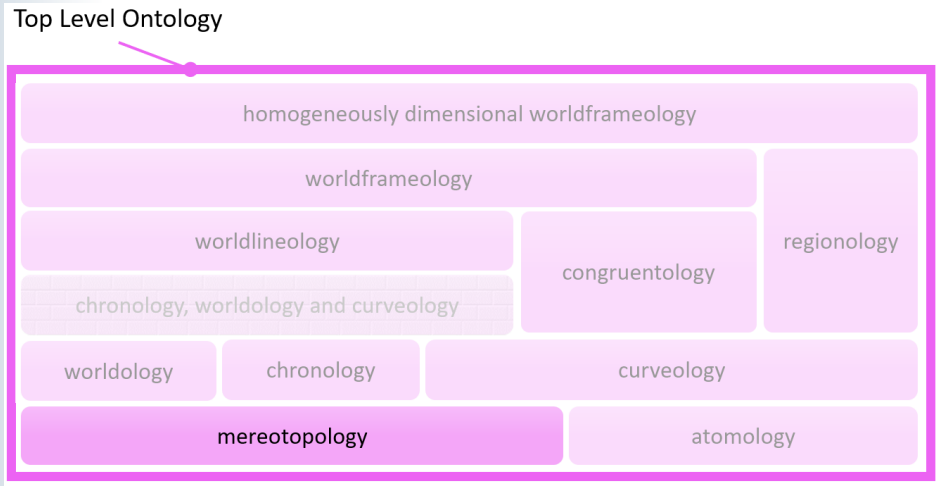
Four-dimensional space-time emerges in the final component

Note: Two types of data component:
1. module
2. mortar
(to be explained later)

TLO components



Mereotopology

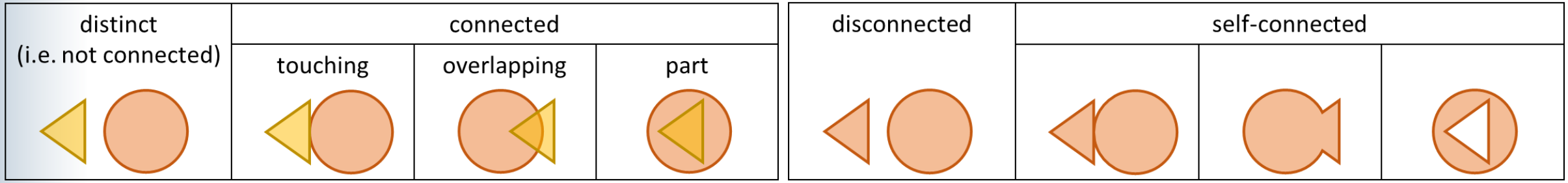


mereotopology introduces **connection**:

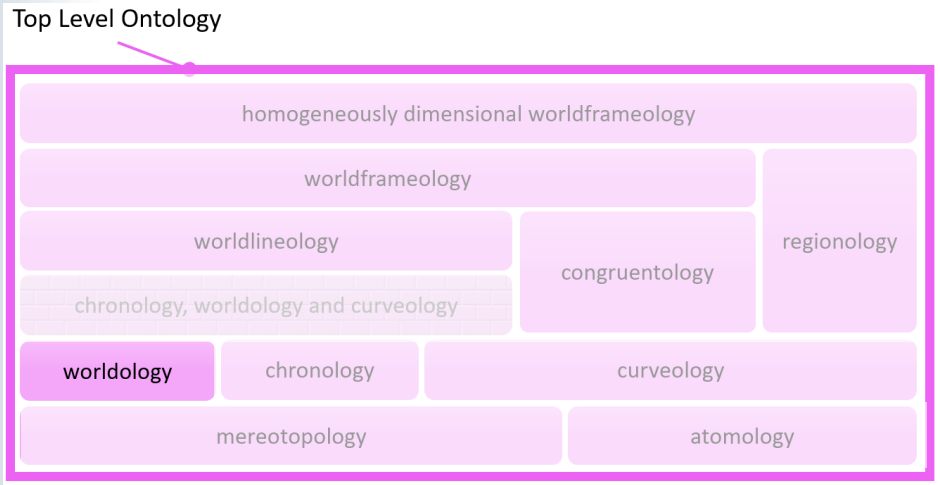
- two individuals can be connected (or distinct)

From this it defines **self-connection**

- an individual whose every part is connected to every other part.



Worldology



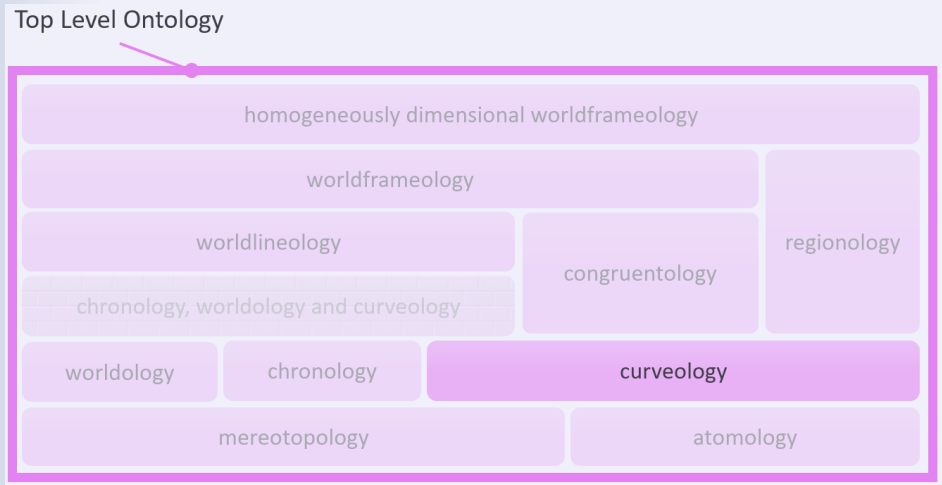
- wordology introduces (possible) worlds
- defined in mereotopological terms as maximally self-connected regions
  - worlds are self-connected individuals that are not part of any other self-connected individuals
  - so different worlds are not connected in any way
    - when we introduce time, we can say that they are not connected spatially or temporally.

This has been called a Lewisian or concretist view.

> "There are countless other worlds, other very inclusive things. Our world consists of us and all our surroundings, however, remote in time and space; just as it is one big thing having lesser things as parts, so likewise do other worlds have lesser other-worldly things as parts."

David Lewis, 1986. On The Plurality of Worlds, p. 2

Curveology

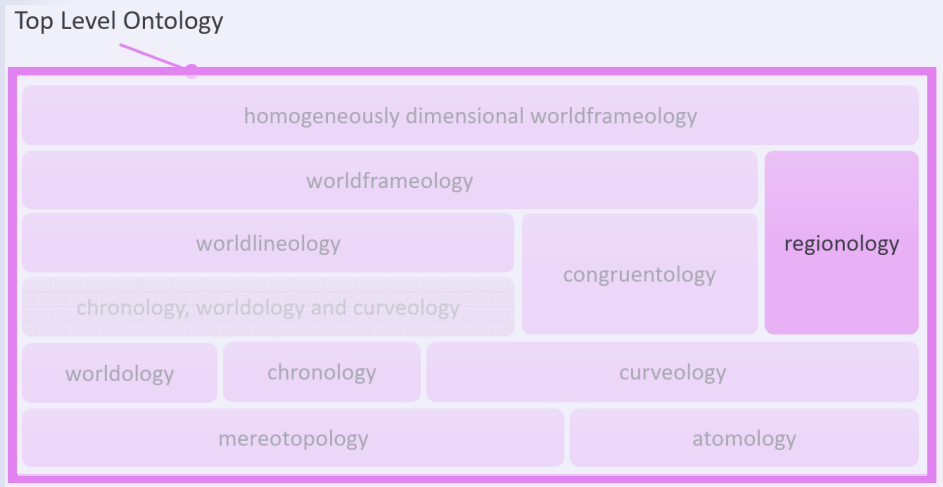


- curveology introduces (simple, open) curves
  - defined using mereotopology and atomology
    - as minimal, self-connected objects containing two atom endpoints
  - are composed of atoms – zero-dimensional objects

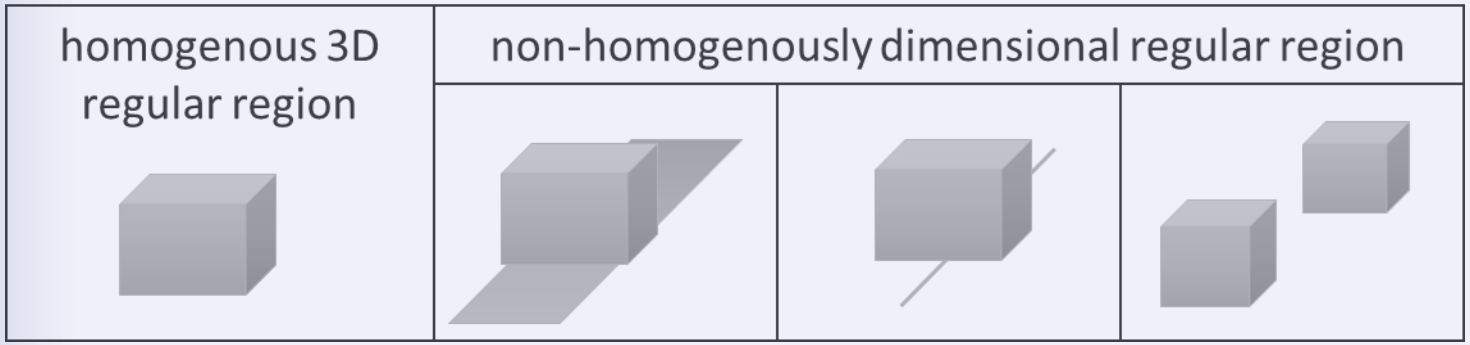
simple open curve	non-simple or closed curves		
	non-simple curve	closed curve	non-simple closed curve

https://mathworld.wolfram.com/SimpleCurve.html
https://mathworld.wolfram.com/ClosedCurve.html

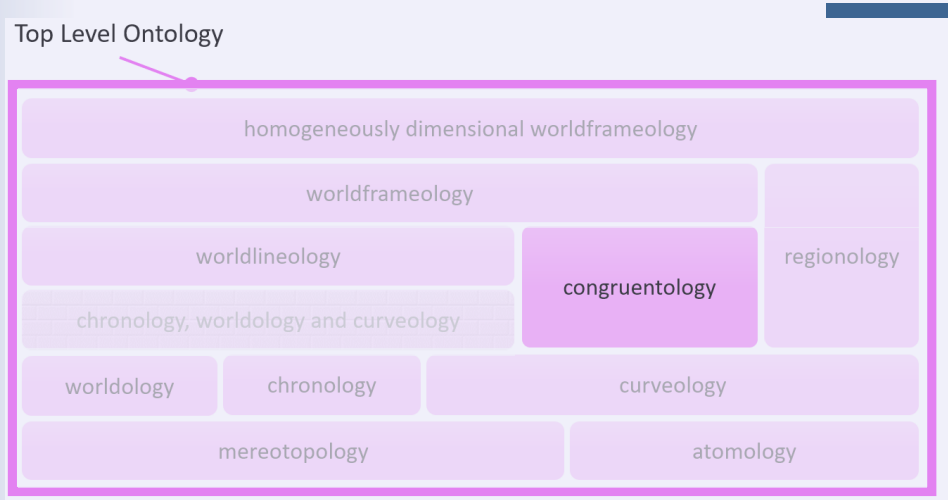
Regionology (dimensionality)



- regionology introduces higher-level dimensional objects, including 4D Regions
- it collects together homogeneously two-, three- and four-dimensional regular objects
  - where regular objects are self-connected
- using mereological operations, such as union and intersection, less regular objects can be generated



Congruentology



- congruentology introduces a notion of congruent curves – a relation over curves (curveology)
- it collects together congruent curves
  - that is those of the same ‘length’
    - this is the basis for metrics

Prior form: chronology and worldlineology

Opportunity to build upon previous work, including:

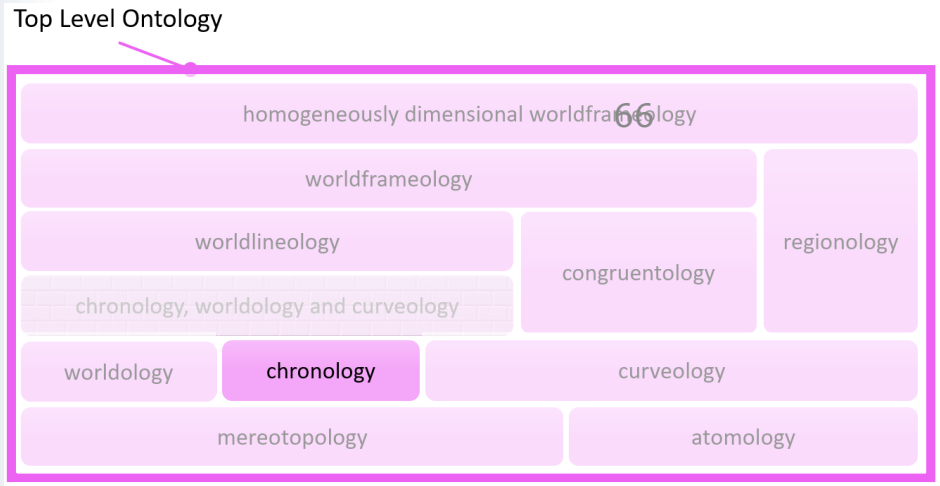
Year	Author	Title
1919	A. N. Whitehead	An enquiry concerning the principles of natural knowledge
1928	R. Carnap	The Logical Structure of the World
1936	B. Russell	On order in time
1939	J. H. Woodger	The Technique of Theory Construction
1963	A. Grünbaum	Philosophical Problems of Space and Time
1981	P. Needham	Temporal Intervals and Temporal Order
1982	C. Lejewski	Ontology: What's Next?

Introduced the name 'chronology'

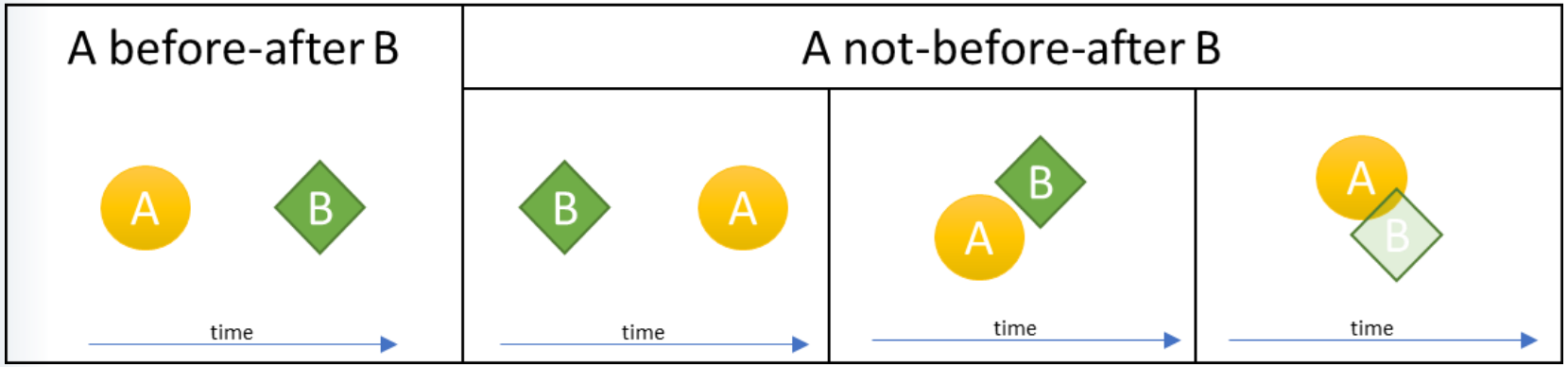
Key architecture:

- time as a before-after relation between individuals
  - (Grunbaum has more places)
- worldlines as characterising space-time

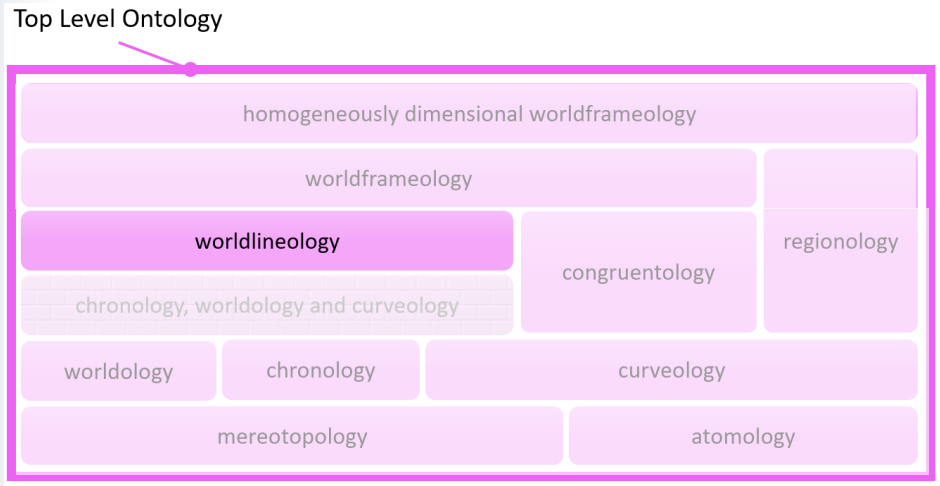
Chronology



- chronology introduces a (completely) before-after relation between individuals
- from this the other temporal relations can be defined

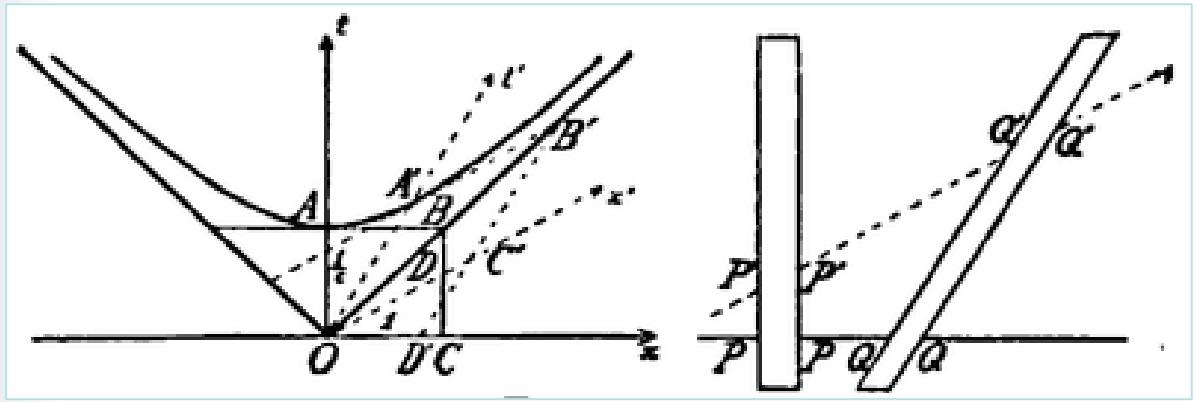


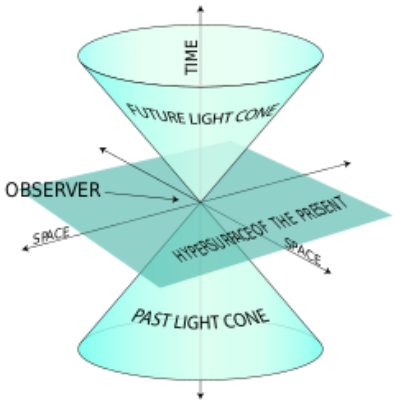
Worldlineology



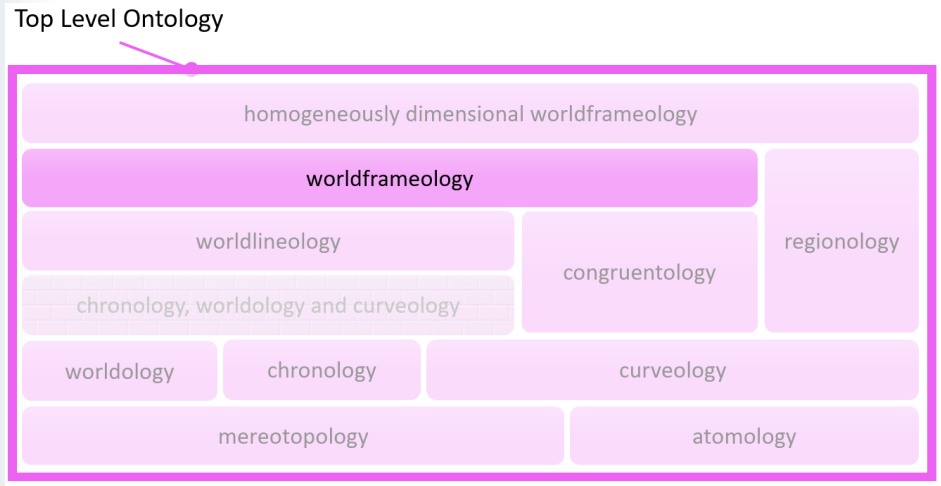
- worldlineology introduces worldlines
- defined in terms of a time-like (chronology) curve (curveology)
  - every two points (atoms) in the time-like curve have to be in a before-after relation

Illustration: Minkowski, Hermann (1909), "Raum und Zeit", Physikalische Zeitschrift, 10: 75–88

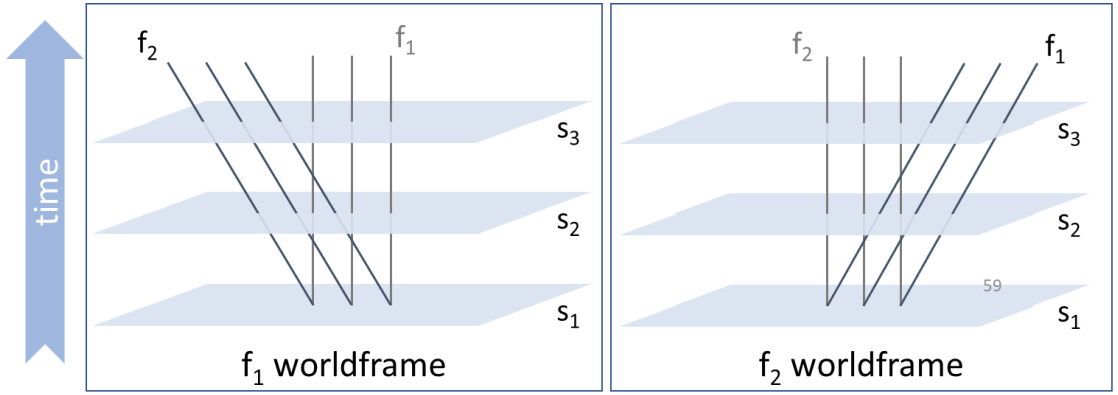


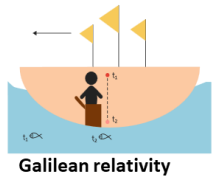


Worldframeology



- worldframeology introduces worldframes
- defined as sets of ‘parallel’ worldlines (worldlineology) that cover space-time, where ‘parallel’ is defined using congruence (congruentology)
- there are typically an infinite number of worldframes



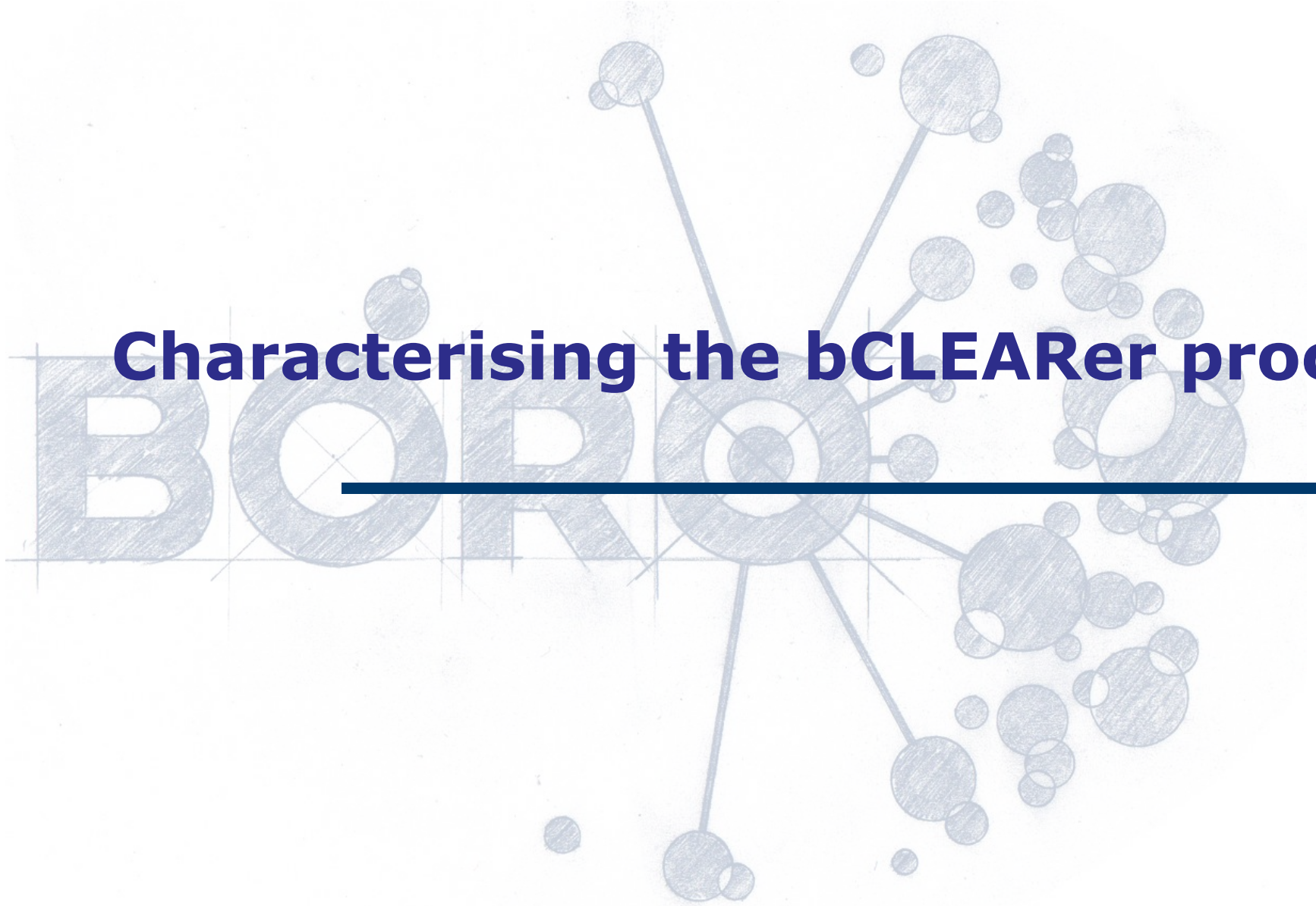


See also:

Year	Title	Link
2019	Coordinate Systems: Level Ascending Ontological Options	https://borosolutions.net/coordinate-systems-multi-2019
2013	Air Control Means: An ‘Improving Precision’ Case Study	https://borosolutions.net/air-control-means-ontobras-2013
2013	Geospatial and Temporal Reference: A Case Study Illustrating (Radical) Refactoring	https://borosolutions.net/geospatial-temporal-reference-ontobras-2013
2011	An information model for geospatial and temporal references	https://borosolutions.net/qq2011-model-geospatial-temporal-references

Summary - bare Quinean view

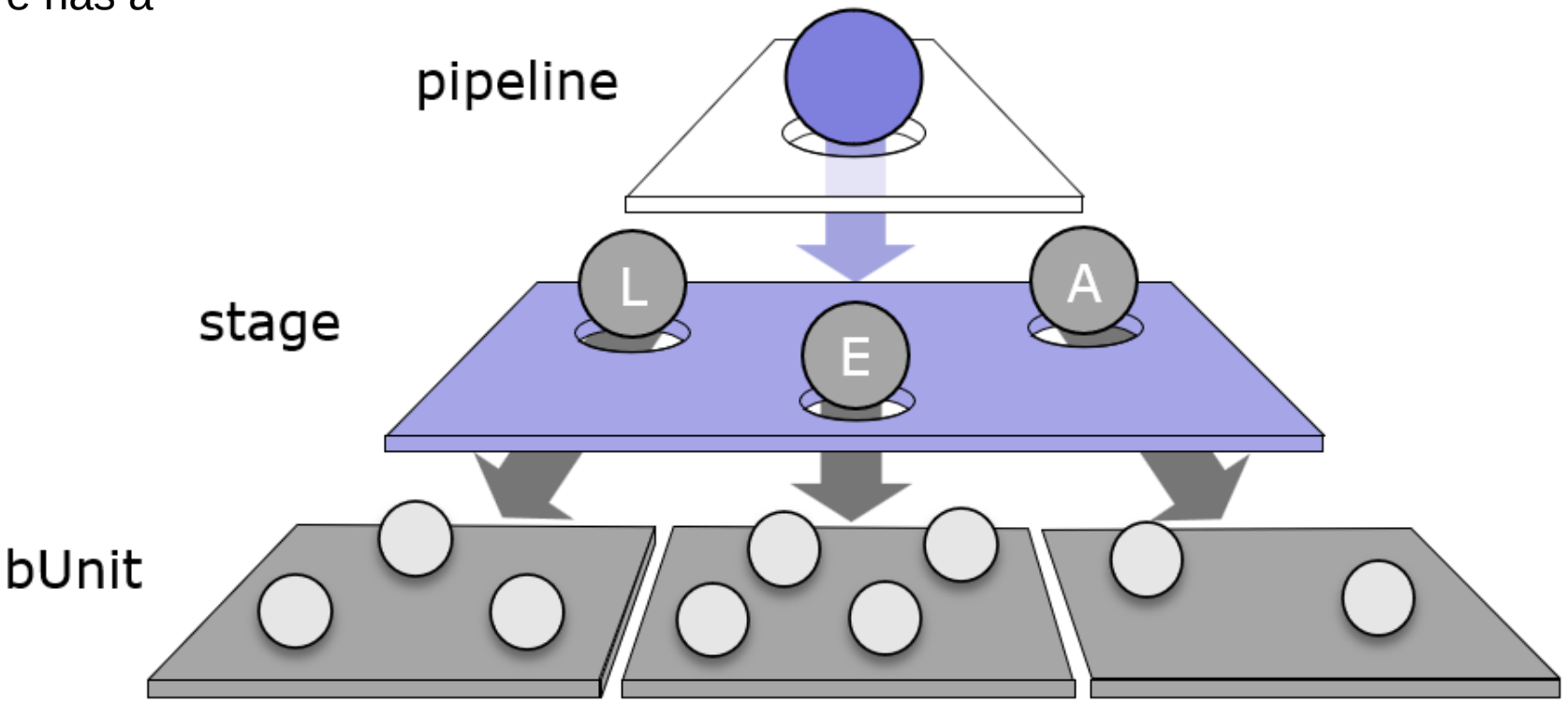
- Quine:
  - ‘What is there?’ … It can be answered, moreover, in a word—‘Everything’—and everyone will accept this answer as true.
- The constructional machinery can (using a single, unified process):
  - give an account of ‘everything’ (*object completeness*), and
  - explain what ontological category everything has (*categorical completeness*)
  - Provide a single explanation of their identity criteria (*common identity criteria*)
    - (extensional based on the type of constructor and its input)



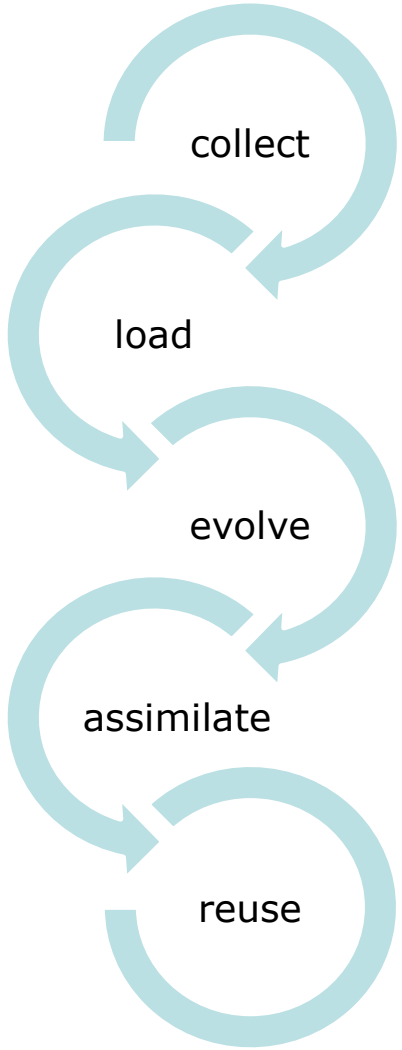
Characterising the bCLEARer process

A three-level framework

The process architecture has a three-level framework.



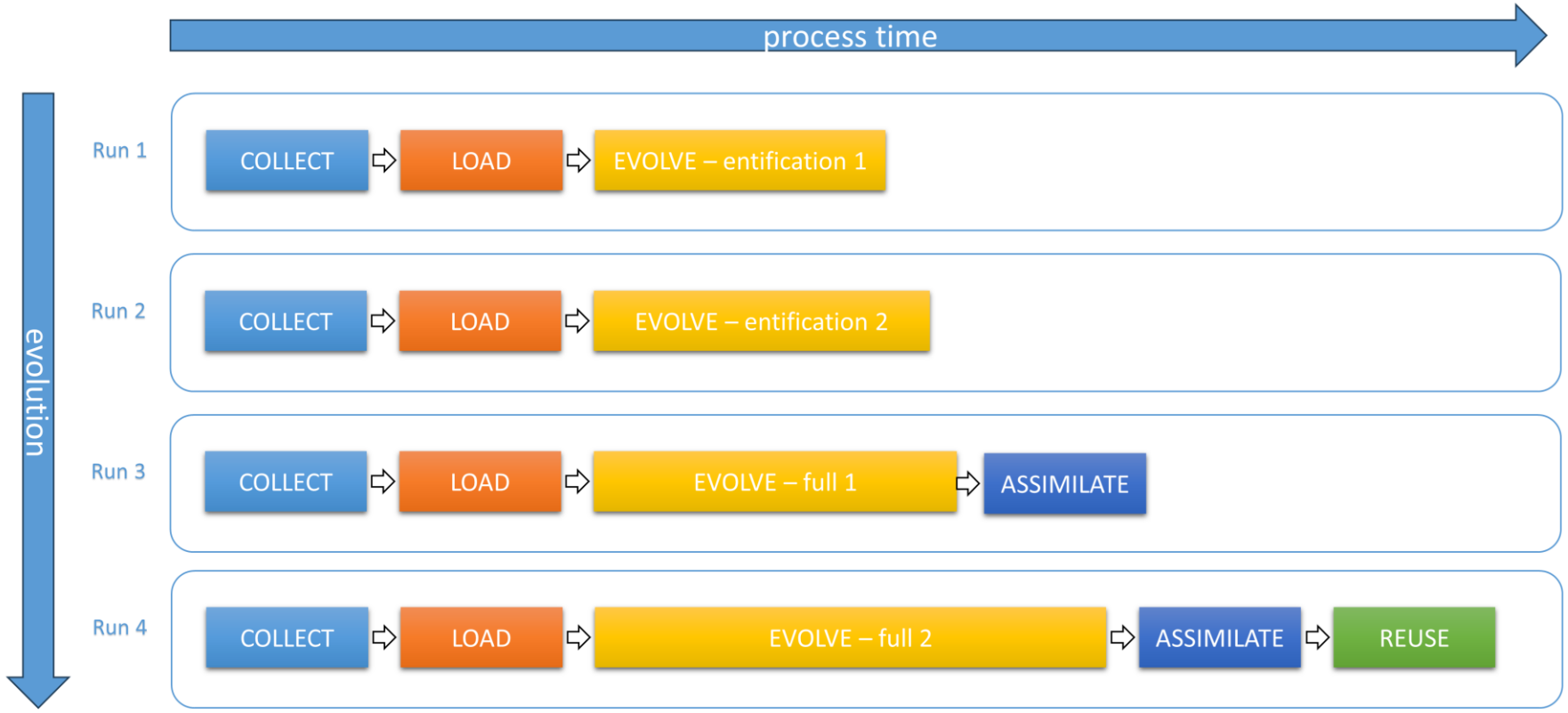
bCLEARer's five stages



stages	
Collect	• Collect the datasets • Establish the broad scope of the process
Load	• Select the data in scope • Translate the data into the cells
Evolve	• Reveal the underlying semantics • Mine the ontology
Assimilate	• Merge the run into the full model • Establish a single integrated model
Reuse	• Export into applications and (re-)use

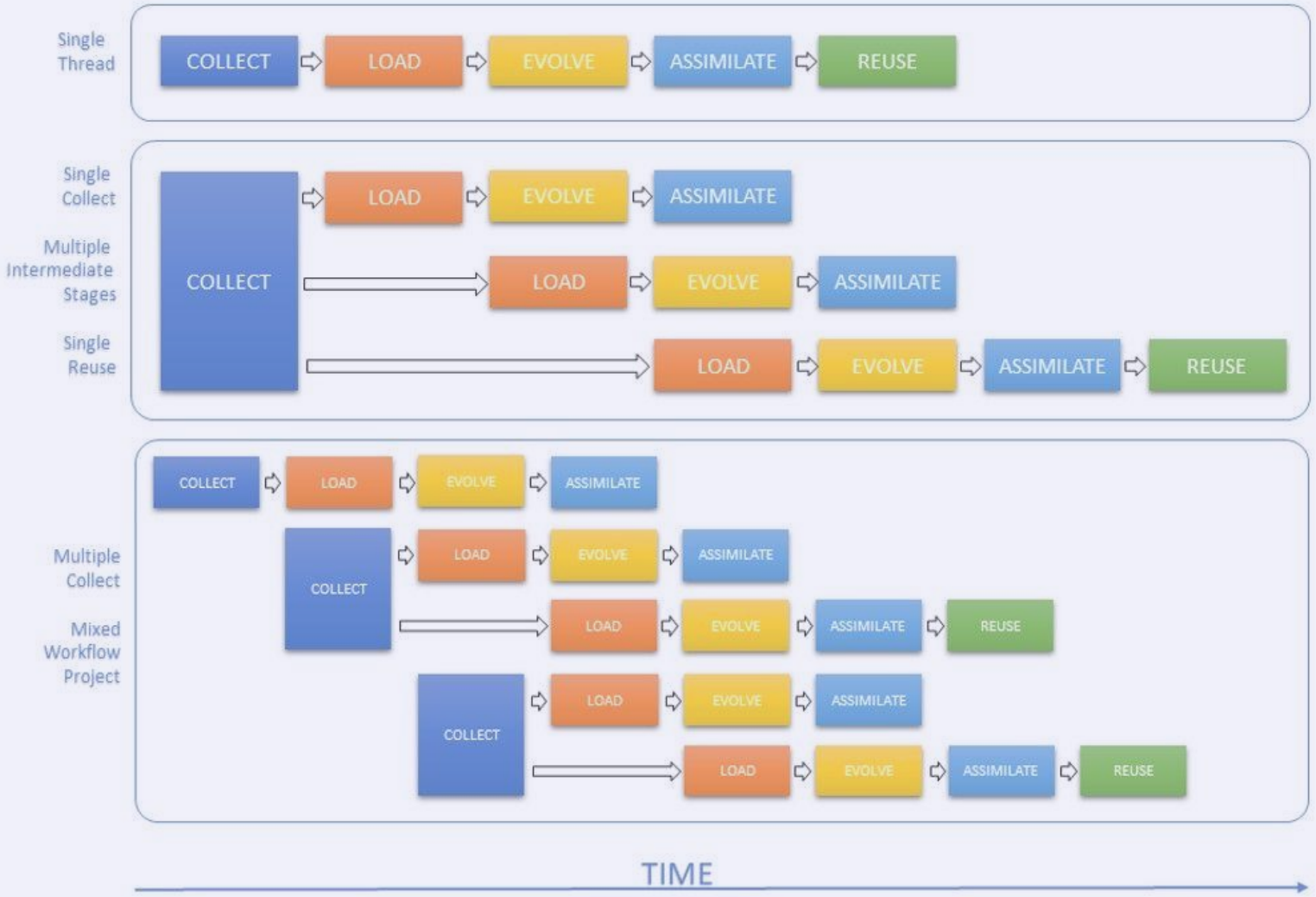
Process evolution - extension

Over time, the process evolves as new stages emerge.



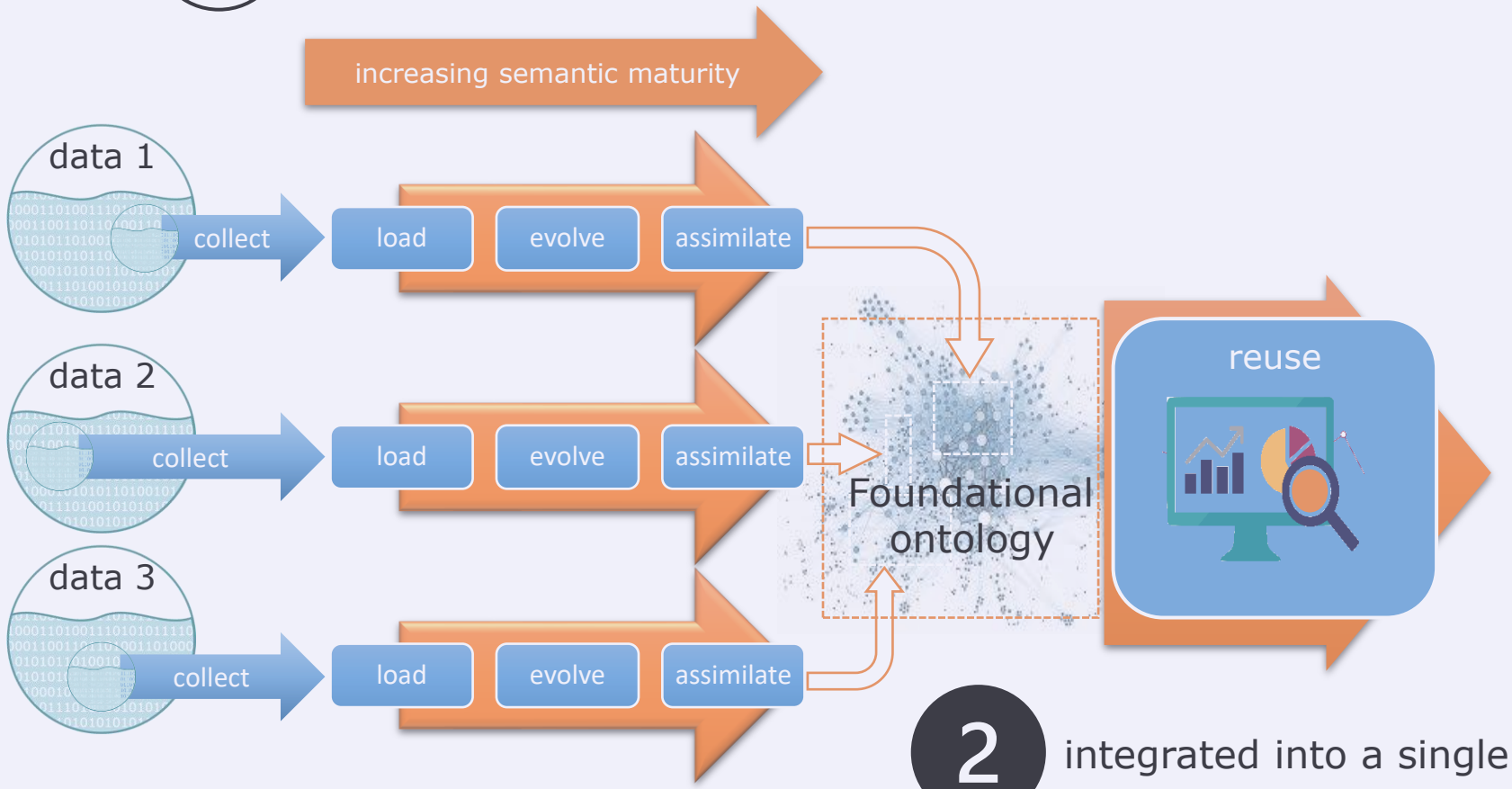
Process evolution - multiplicity

There can be multiple process evolving over time.



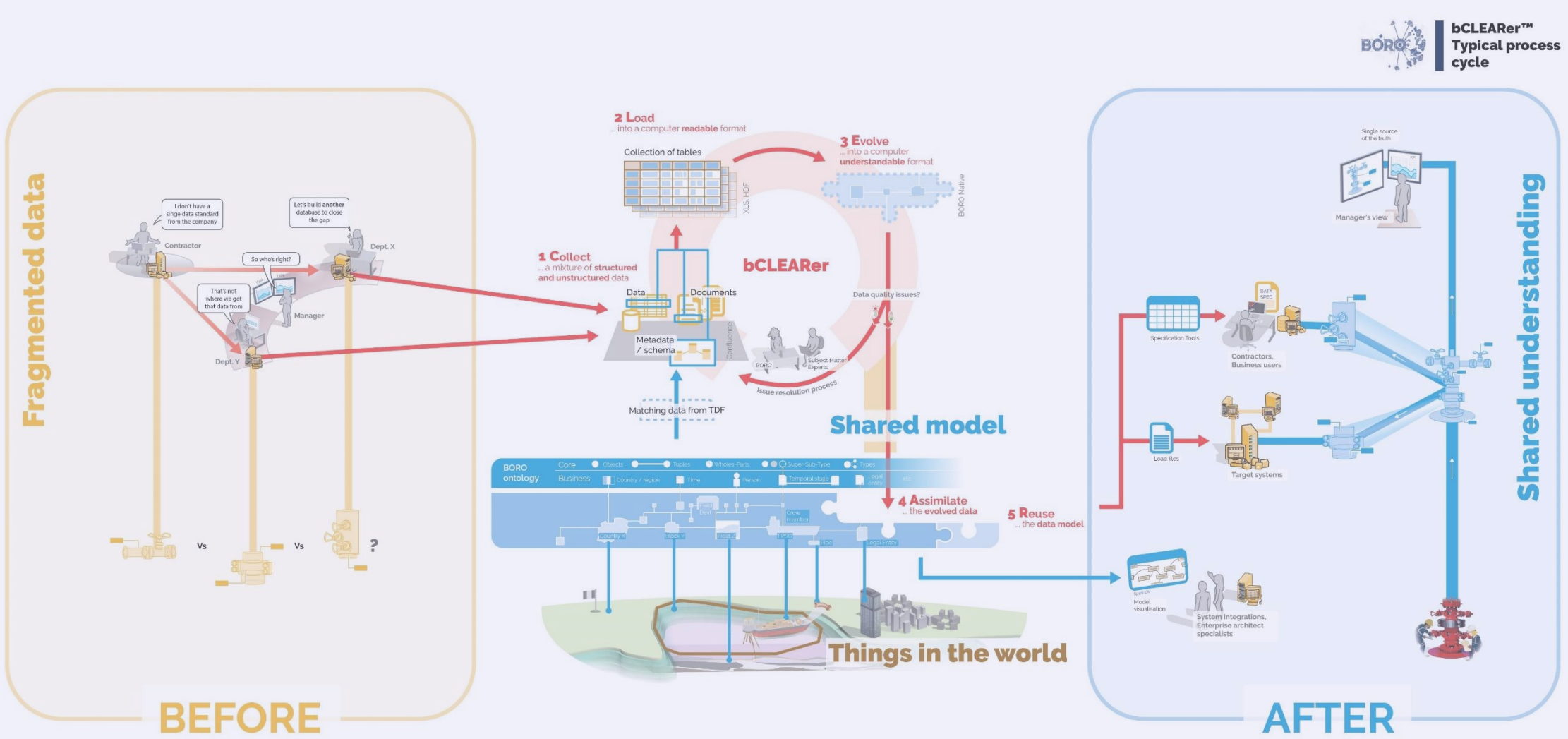
Multiple inputs, multiple runs, integrated

1 a repeated sequence of automated processes:
a **scalable way to systematically improve** semantic maturity

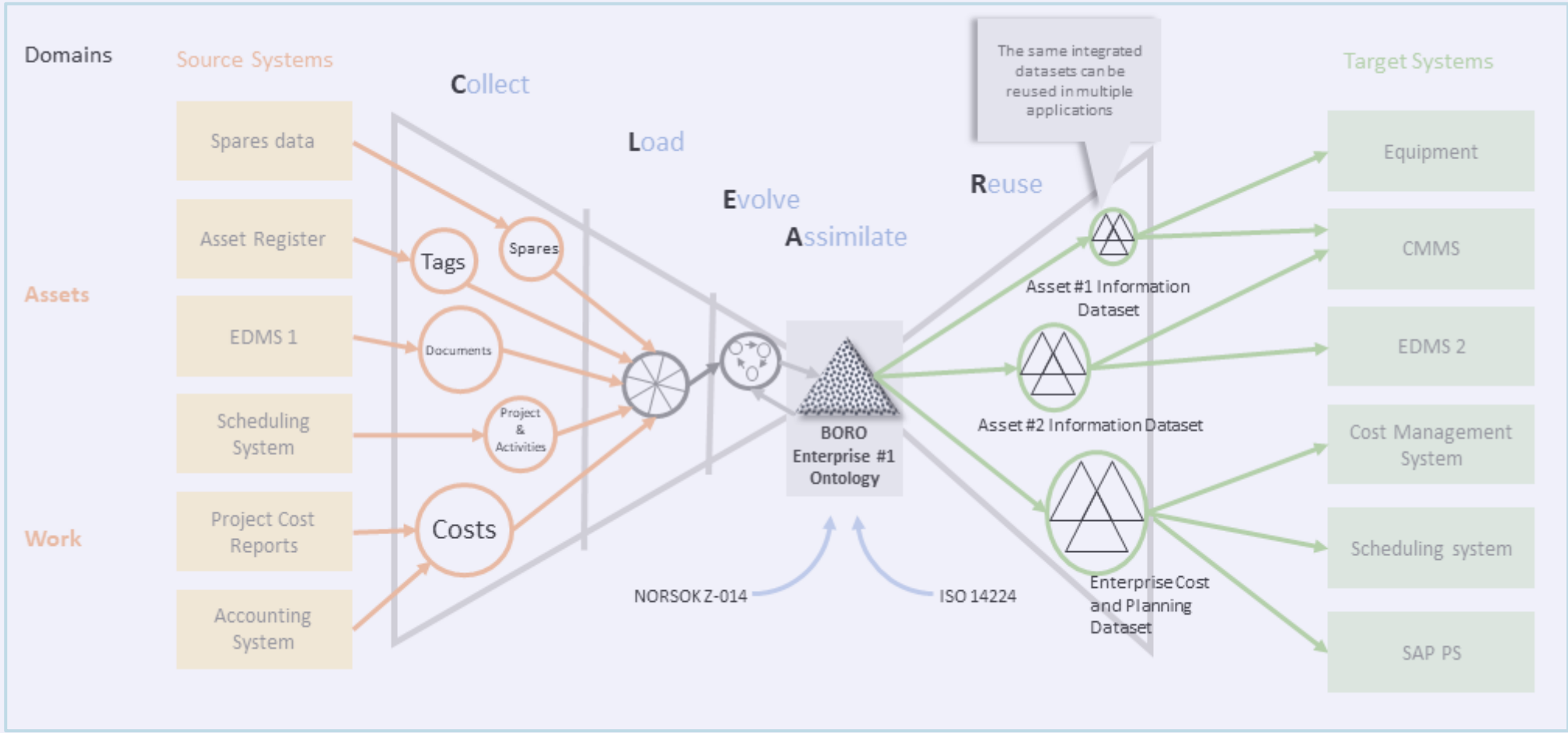


2 integrated into a single foundational ontology

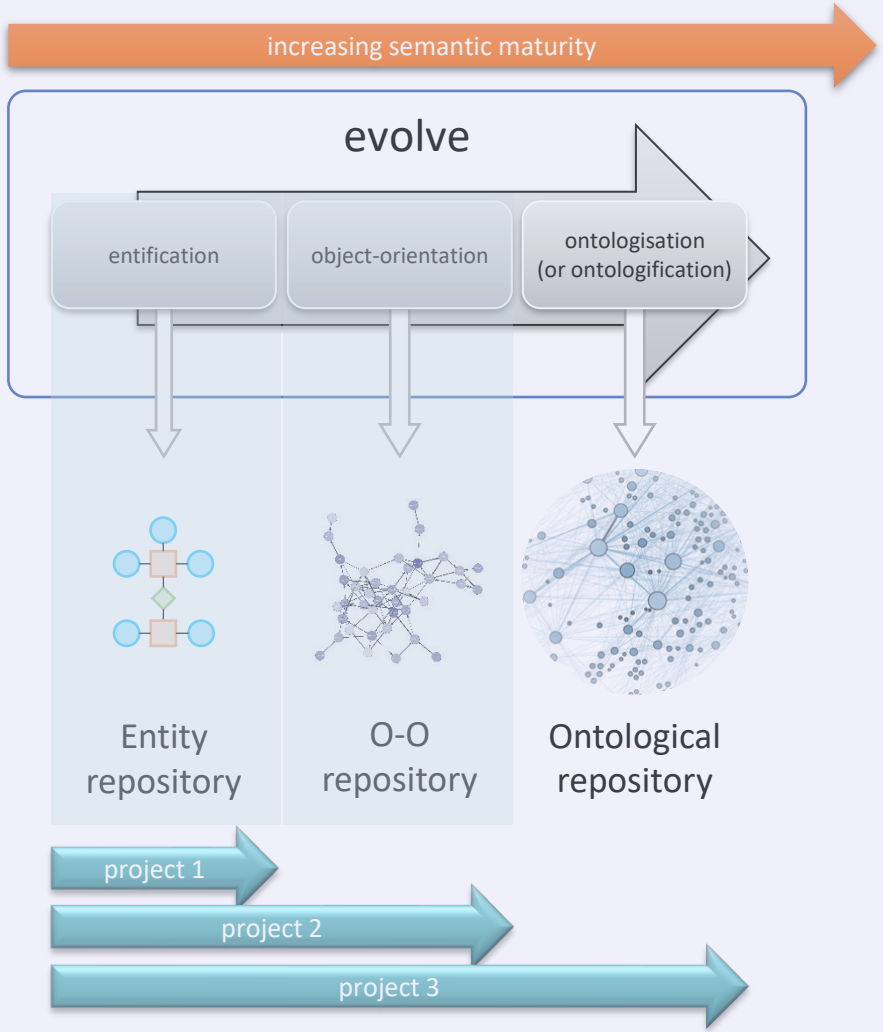
The user perspective

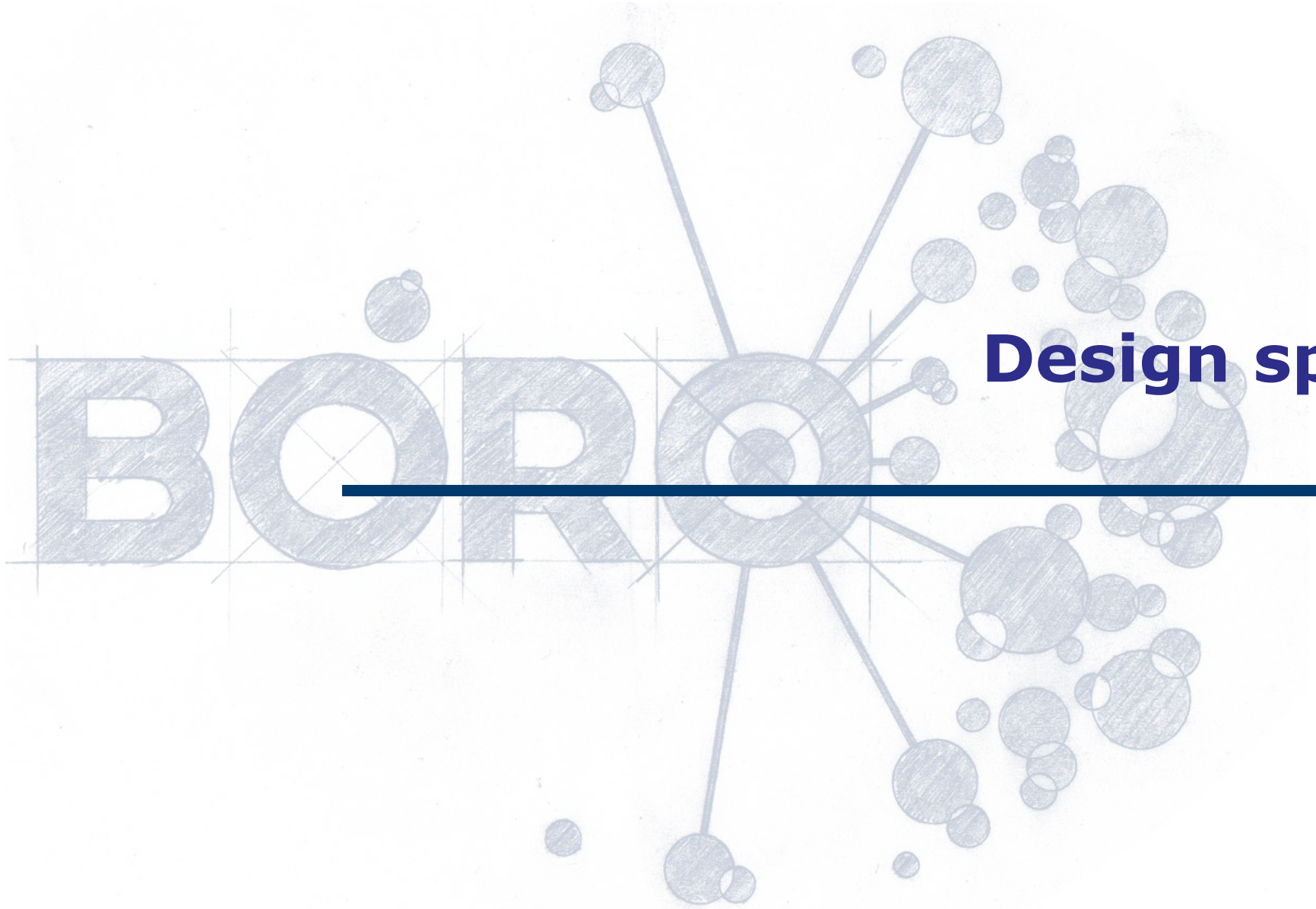


Schematic view of one bCLEARer engine



Increase maturity in pragmatic steps





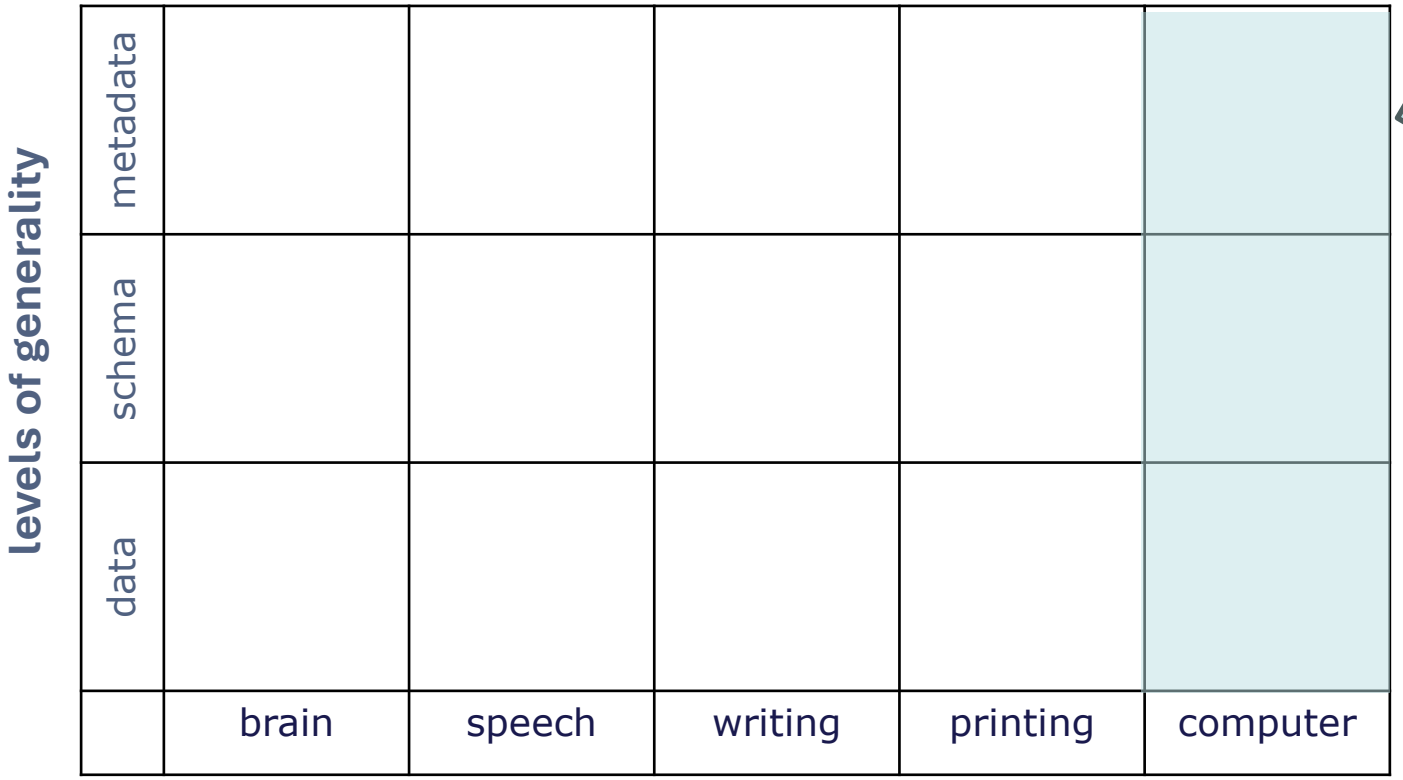
Design space

Levels of generality

- One can broadly divide information into levels of generality.
- From a syntactic ‘data’ perspective, these are the natural levels:
  - metadata,
  - schema and
  - data.
- For our purposes here, these are a good enough rough proxy for the semantic levels to make the substitution fair for our broad classification
  - top, the most general - categories,
  - middle – universals/types and
  - bottom level - the most specific – typically particulars.
- We need the syntactic perspective we often start with ‘raw’ structured information where this is simple to identify.

Design Space – in two dimensions

two-dimensional design space - exploitation



Target
1) computer level digitalisation
2) cover all levels of generality

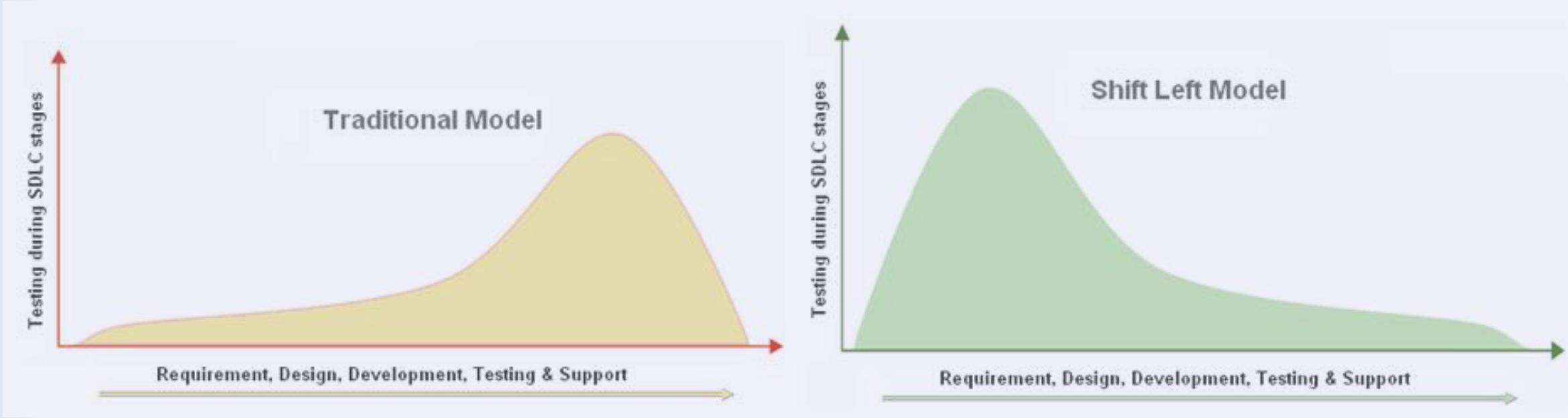
Often omit data – especially large datasets

Often work with unstructured data – even brain data

Information pathway

- An information pathway refers to the flow and transformation of data or knowledge from its source to its intended destination.
  - It can occur within a system (such as a human brain, an organization, or software application) or between multiple systems.
  - It also occurs in an ontologization process
- We look at the way the ontologization process engages in the information pathway with the two-dimensional levels over time.

Exploiting the new space involves a ‘shift left’



Exploiting the space involves shifting the introduction of data (generality) and computing (digitalization) to as early in the project as feasible.

Smith, L. (2001). "Shift-left testing". Dr. Dobb’s Journal, 26(9), 56–ff.
Bahrs, P. (2014). Shifting Left - Approach and Practices. https://www.slideshare.net/Urbancode/shift-left
Firesmith, D. (2015). "Four types of shift left testing". Podcast, Software Engineering Institute Website, September.

Architectural issues

- Use a micro architecture
  - not a monolithic architecture
  - a pipeline built of micro transformations
- Design for inspectability
  - ensure data identity traceability

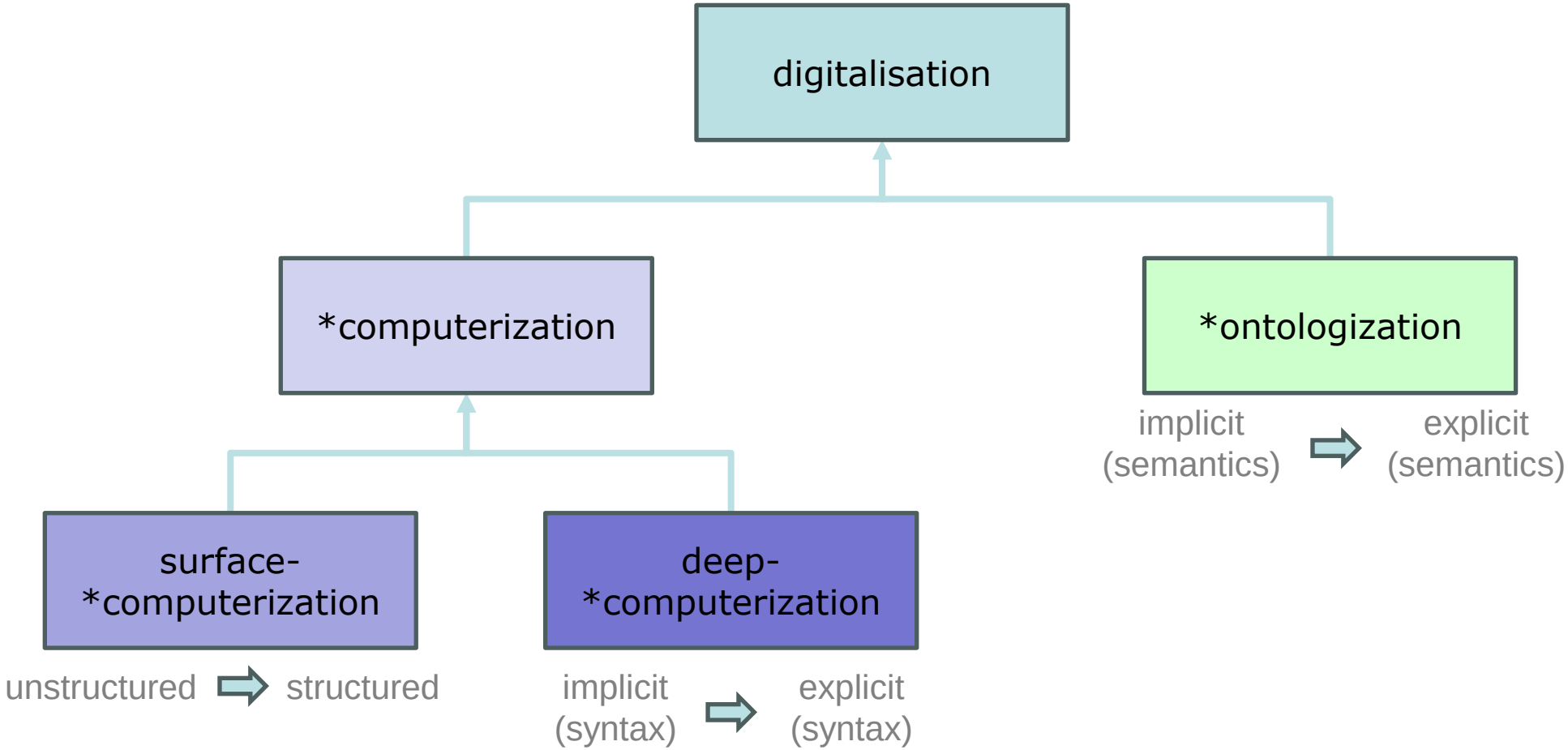
Digitalisation Process Factorisation

*Computerization versus *ontologisation

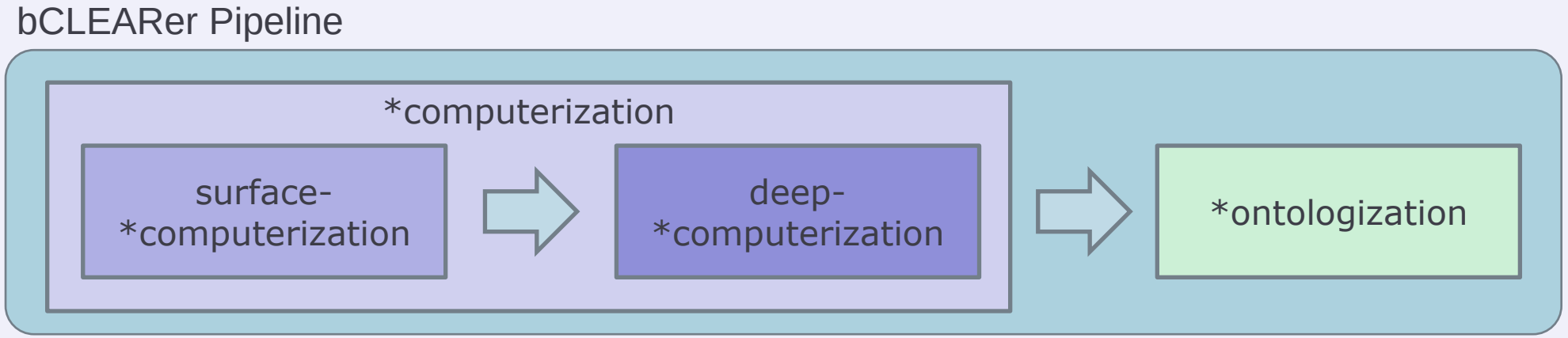
- *Computerization
  - transformations that make the intended interpretation explicit
  - avoids leading the interpretation
  - From an ethnographical perspective, this is a kind of ‘surfacing’.
    - the details are technical and “excursions into this aspect of information infrastructure can be stiflingly boring”.
    - This means that large parts of the infrastructure are often invisible,
      - S. L. Star, ‘The Ethnography of Infrastructure’, American Behavioral Scientist, vol. 43, no. 3, Art. no. 3, Nov. 1999
- *Ontologization
  - shifts towards the preferred ontology
    - using the foundational ontology
  - embraces leading the interpretation
    - moves in small clear steps

- Chris Partridge, C., Mitchell, A., de Cesare, S., Beverley, J. (2025). "Broadening Ontologization Design: Embracing Data Pipeline Strategies". https://www.academia.edu/129382330

Factorization of digitalisation



Ordering the factored components



Post-Ontology

De se agentology

Introducing a *de se* perspective – the indexical ‘I’

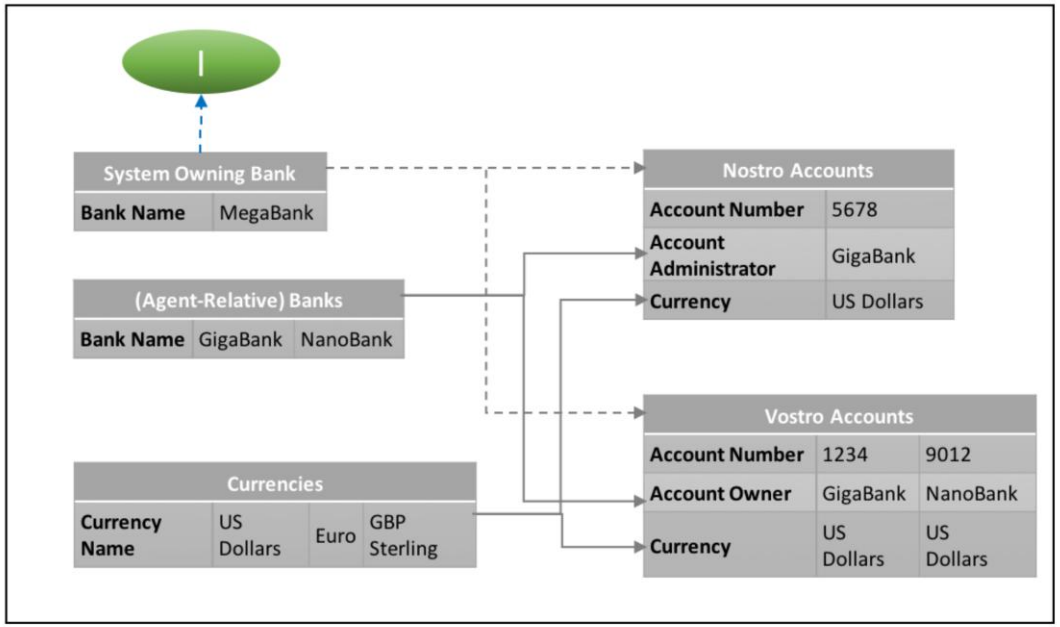


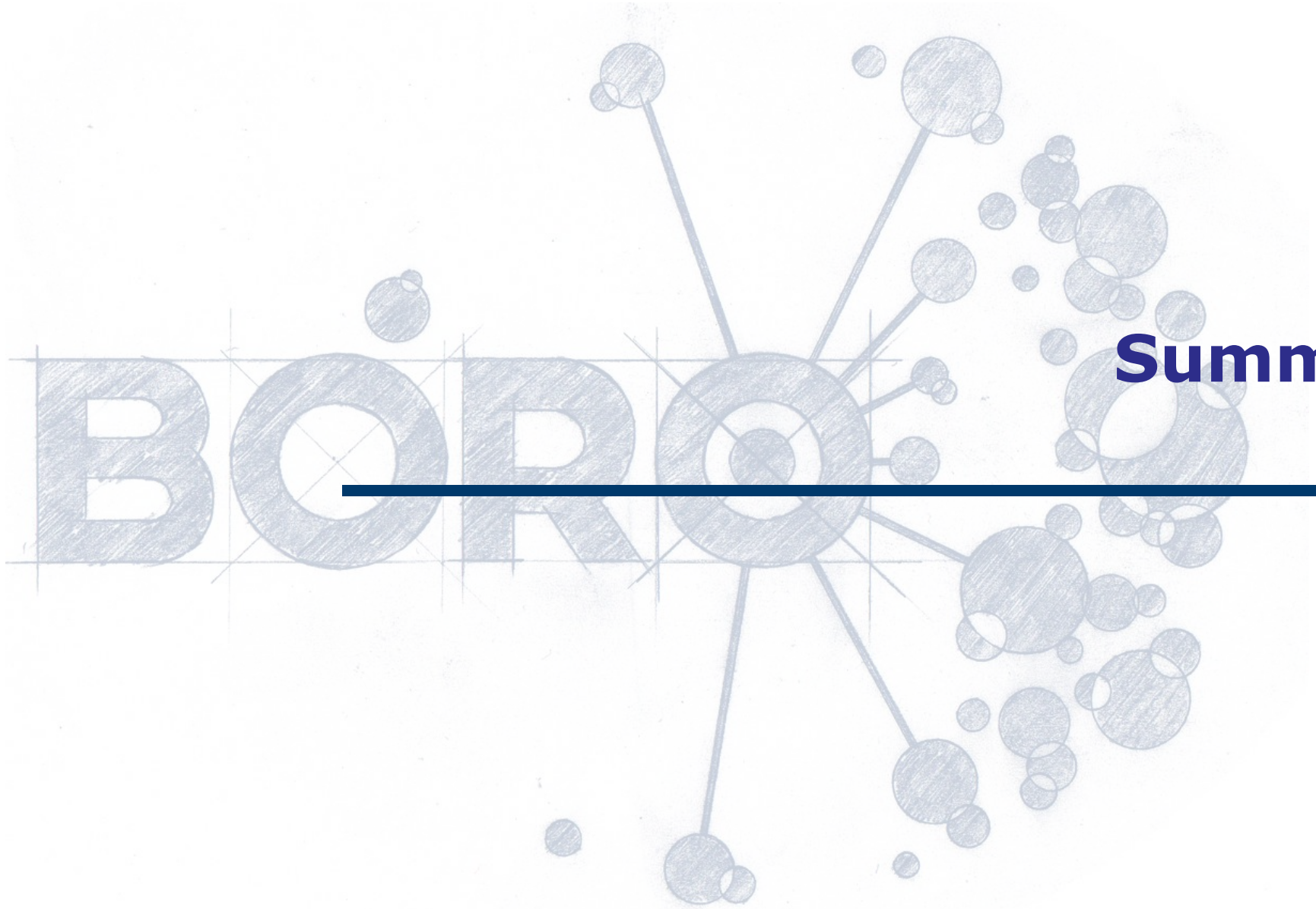
Figure 4: Another more typical view - Mega-Bancology.

Partridge, C., de Cesare, S., Mitchell, A., León, A., Gailly, F., & Khan, M. (2018). Ontology then Agentology: A Finer Grained Framework for Enterprise Modelling: *Proceedings of the 6th International Conference on Model-Driven Engineering and Software Development*, 454–463. https://doi.org/10.5220/0006606304540463

De se doxastology

- Developing a de se doxastology
  - for uncertain information
    - two dimensional Lewisian semantics

- See: Chris Partridge, C., Mitchell, A., Cola A., (2025). "Digitalizing Uncertain Information". https://www.academia.edu/125111898/



Summary

Summary

- BORO foundational ontology is promulgated as a
  - a toolkit for ontological analysis
- Characterised the foundational ontology in three ways
  - ontological categories
  - bare Quinean structure – using a constructional approach
  - broad ontological architecture (and patterns)
- Proposed a micro transformation architectural pipeline process to inject the foundational ontology into the interoperability processes

Questions

THE END.